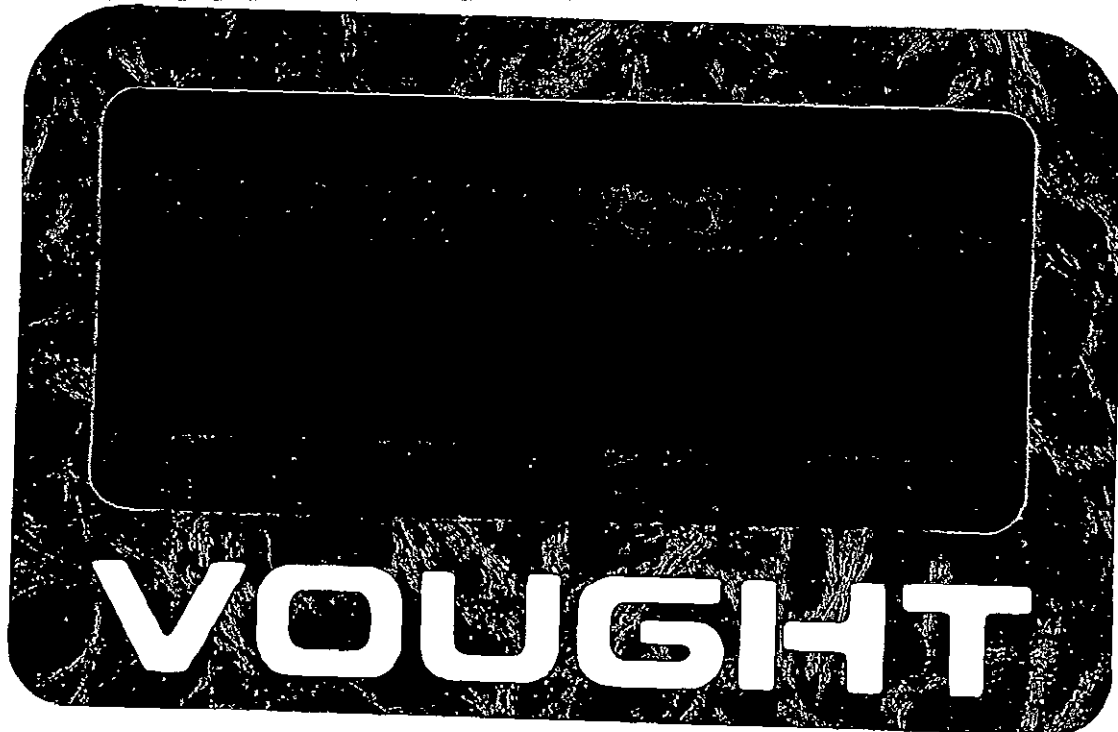


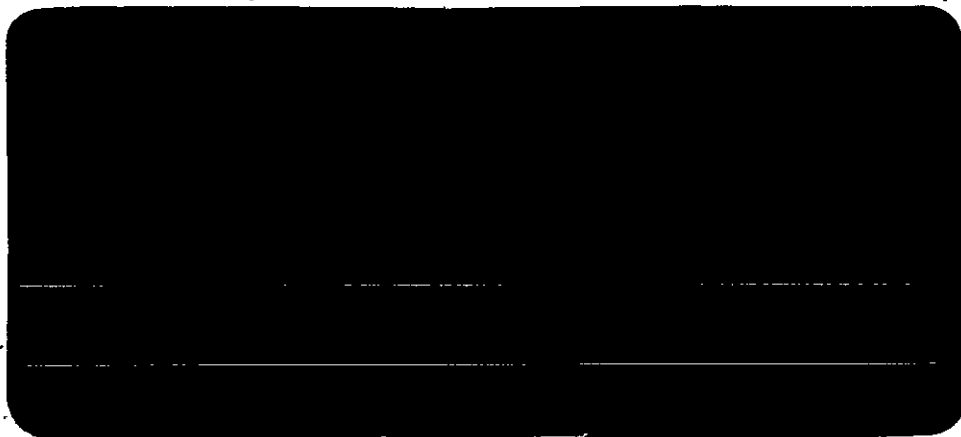
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FINAL REPORT

SILVER-TEFLON COATING IMPROVEMENT

Report No. TL69-71

December 23, 1976

PREPARED UNDER CONTRACT NAS9-10534

FOR

NASA JOHNSON SPACE CENTER

CREW SYSTEMS DIVISION

Prepared by:

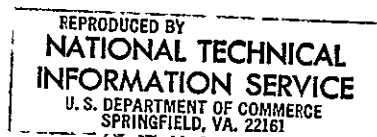
M. W. Reed  
M. W. Reed  
Principal Investigator

Approved by:

W. E. Agan  
W. E. Agan  
Structures Technologies

Approved by:

R. L. Cox  
R. L. Cox  
Thermal R&D



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## S U M M A R Y

1. This report summarizes work accomplished by Vought relative to silver/Teflon thermal coating over the time period July 1973 to October 1975. The main body of the effort reported was carried out under Contract . . . NAS9-10534, although other data which has a bearing on the development of silver/Teflon is also included.
2. The primary effort of the work reported has been to develop a combination of an adhesive and an application procedure from a laboratory scale to one useful for reproducible manufacture in quantities to coat the approximately 1600 sq. ft. of Shuttle Orbiter radiator panels.
3. At the beginning of the subject time period, two adhesives/application processes had been developed which were suitable as full scale coating system candidates. Through the course of the work, Permacel P223 and General Electric SR-585 adhesives were selected, evaluated, scaled up, and tested on full scale prototype radiator panels. At the end of the period, a workable coating system and process, based on P223, was available for use on the Orbiter panels, although some improvement in coating adhesion was still desirable.
4. The most significant accomplishments during this time period are listed.
  - (a) Flight size hardware for Space Shuttle can be successfully coated with silver/Teflon thermal control material.
  - (b) Silver/Teflon coating with P223 adhesive can be manufactured reproducibly.
  - (c) Thermal-vacuum test exposure does not affect the optical or mechanical properties of the coating.
  - (d) Application of silver/Teflon to components containing cutouts, small radii, and minor compound curves was demonstrated.
  - (e) Scale up from laboratory adhesive batches to production size quantities by the silver/Teflon supplier using equipment such as roll laminators was only partially successful with the high tack SR 585 silicone. Thus the P223 adhesive, which is available in the form of a double-backed tape, is recommended for Orbiter application.

## 1.0

INTRODUCTION

The use of silver/FEP Teflon\* film as a thermal control surface for space radiators is based on a favorable solar absorptance/emittance ratio in the 0.08 to 0.1 range, a stable solar absorptance varying between 0.06 and 0.08, high transparency, and minimal degradation in the charged particle-ultraviolet radiation environment of near-space<sup>(1)</sup>. The silver/FEP thermal control material consists of FEP Teflon film, type A, with a layer of silver deposited on one side by vacuum evaporation to a thickness of 1250 A.U. The silver is protected by an evaporated overlay of Inconel 600\*\* to a thickness in the 250 A.U. range. The Inconel serves to retard chemical attack on the silver, aids the handleability of the film, prevents mechanical damage to the silver, and furnishes a bondable surface for the film. The silver/FEP functions as a second surface mirror since the attachment from the radiator panel is to the metallized surface of the FEP; this leaves the bare FEP exposed as the radiating surface. The favorable hemispherical emittance,  $\epsilon = 0.8$  typically, of the FEP is thus retained.

## 2.0

BACKGROUND

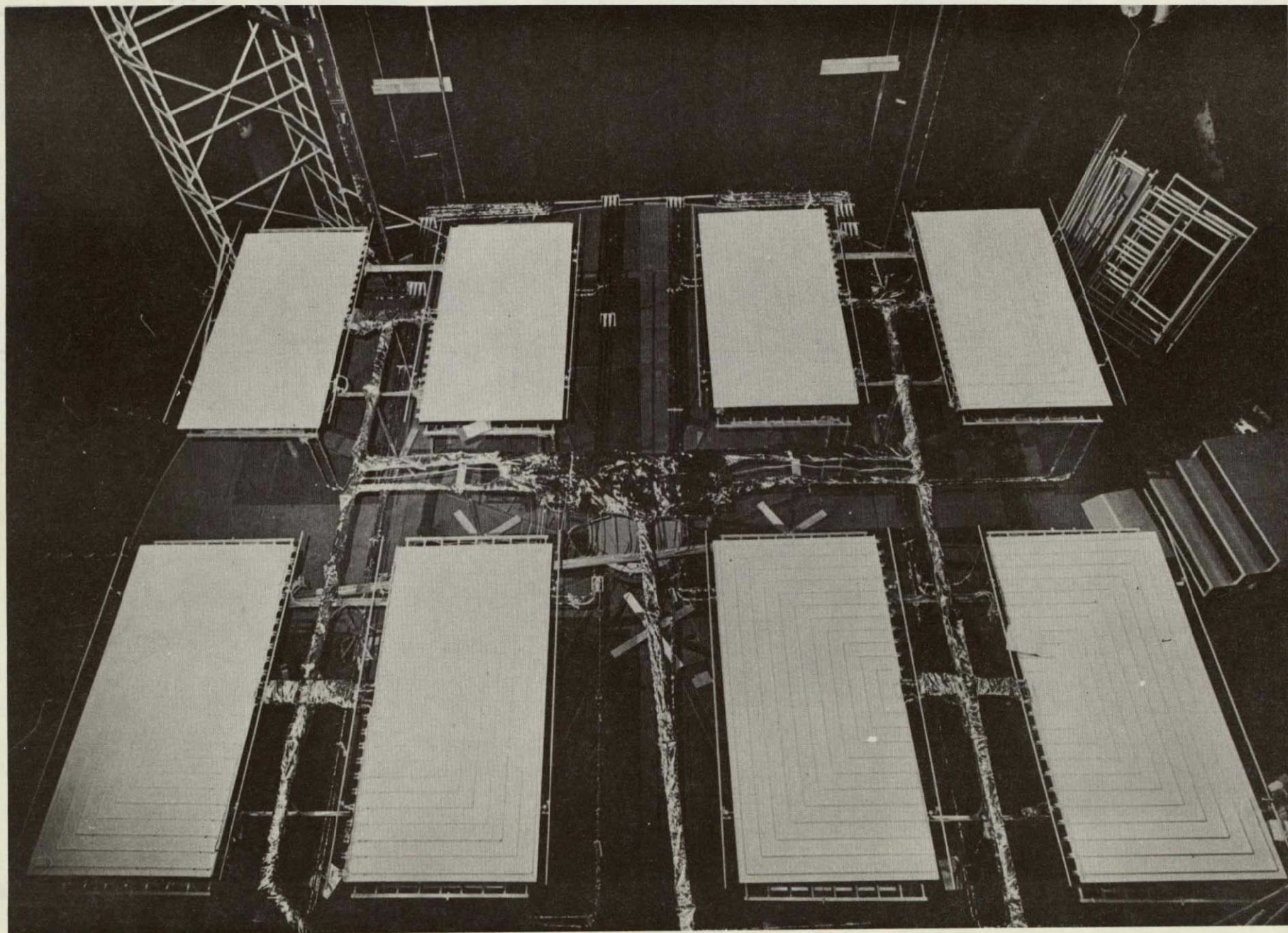
Vought Corporation produced and tested silver/Teflon thermal control coatings on a Modular Radiator System projected for use on the Space Shuttle in April-July 1973. Approximately forty adhesives were subjected to laboratory screening. Seven candidate adhesives were selected from the screening tests and evaluated in a thermal vacuum test on radiator panels similar to the anticipated flight hardware configuration. Several classes of adhesives based on epoxide, polyester, silicone, and urethane resin systems were tested. These included contact adhesives, heat cured adhesives, heat and pressure cured adhesives, pressure sensitive adhesives, and two part paint-on or spray-on adhesives. The panels were tested at the NASA-JSC Space Environmental Simulation Laboratory - Chamber A during the July 9-20, 1973 time span. The eight modular radiators are pictured in Figure 1 arrayed in Chamber A prior to test.

<sup>1</sup> Heaney, J. B., "Suitability of Metalized FEP Teflon as a Spacecraft Thermal Control Surface", AIAA paper 71-AV-35, AIAA Environmental Control Conference, July 1971.

\* DuPont Trademark

\*\* International Nickel Co. Trademark





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FIGURE 1. MODULAR RADIATOR COATINGS TEST/CHAMBER A/NASA/JSC

Consideration in choosing adhesives was to obtain the widest variety of chemical types which might function in the anticipated -280°F to +175°F thermal environment.

Table I lists the adhesives selected for evaluation on the modular radiator panels.

TABLE I ADHESIVE DEVELOPMENT PROGRAM MATERIALS, JULY 1973

<u>IDENTIFICATION</u>	<u>TYPE/APPLICATION</u>	<u>INVESTIGATOR</u>	<u>PANEL NO.</u>
RTV 560	Silicone/2 part brush	Vought	2
Mystic A117	Silicone/contact	Langley	7
SR585	Silicone/transfer laminate	McDAC	3
Permace1 P-223	Silicone-Kapton/transfer laminate	Vought	5
Crest 7343	Urethane-aluminum/2 part hot mix	Langley	6
Adiprene L-100	Urethane/2 part hot mix	Goddard	8
Adiprene L-167	Urethane/2 part ambient mix	Vought	
G401903	Polyester/transfer laminate	Sheldahl	4

Variations in the size of the silver/FEP film as it influenced handling and coating operations were also investigated. For this reason silver/FEP film in widths from 1 inch to 48 inches was specified from the vendor, Sheldahl Corp. Conclusions from the studies included: (a) the coatings attached with four of the adhesives, two silicones and two urethanes, had no changes develop during the thermal-vacuum test; (b) the most promising adhesives were the silicones, Permace1 P223 and G.E. SR585, which were applied to the silver/FEP Teflon film to form a laminate tape; (c) the urethanes have the disadvantages of a potentially carcinogenic curing agent and difficult application process; (d) the laminate adhesives in tape form required a vacuum bag/heat cure to adhere during the cryogenic temperature excursion; (e) Adhesives with attractive thermal performance properties may be impractical for application to hardware for reasons such as high tack or bubble formation during cure.

The silver-Teflon development effort between the Modular Radiator Coating work, July 1973, and the study of an autoclave cure process for the Orbiter radiator silver-Teflon, October 1975, was not documented. This report summarizes a variety of endeavors at Vought relating to silver-Teflon coating improvement during this period. In view of the fragmented nature of this work, a chronological format was deemed appropriate.

EVENT CHRONOLOGY

July 25, 1973: Dr. Bruce Marcus, Mgr. Heat Pipe Projects, and Paul Mock of TRW, Redondo Beach, CA called regarding coating 54" x 21" x 0.040" heat pipe radiators on both sides with silver-Teflon; ancillary parts to be coated also. TRW will send a drawing in one month for estimating five assemblies. Work to be scheduled for coating about November, 1973.

August 14, 1973: Bill Jacobi Sheldahl, called:

(a) wanted to put an input from Sheldahl in our pitch to Walt Guy on future silver-Teflon improvement work.

(b) reviewed the TRW drawing from which we will bid coating the heat pipe radiator.

August 15, 1973: Input on future silver-Teflon improvement work given to Walt Guy.

August 16, 1973: Bill Morris of Crew Systems Division called. Walt Guy Branch Chief, CSD, received a favorable review of his presentation to Max Faget, Space

Shuttle Engineering Director, concerning silver-Teflon thermal control coating. Guy is prepared to baseline silver-Teflon immediately as the radiator coating. Faget questioned why we did not consider epoxy adhesives.

NOTE: Vought investigated as silver-Teflon adhesives Epon 828, Stycase 2651, Crest 7344. Crest 3170, Eccobond 45, and Hysol 9309 in April - May 1973; these are epoxy adhesives.

August 28, 1973: Vought called Steve Jacobs, NASA/JSC, SMD; Jacobs is sending outgassing data for inclusion in the silver-Teflon coating report for NAS9-10534. Jacobs wants to work with Vought to avoid duplication in the silver-Teflon follow-on.

August 29, 1973: Modular Radiator Panels #1, 2, 4, and 7 have been received at Vought SES Laboratory. The other panels remain at NASA/JSC.

August 30, 1973: Paul Mock, TRW, called: (a) asked for ROM quote on 6" x 12" silver-Teflon coated thermal vacuum test article, Figure 2.

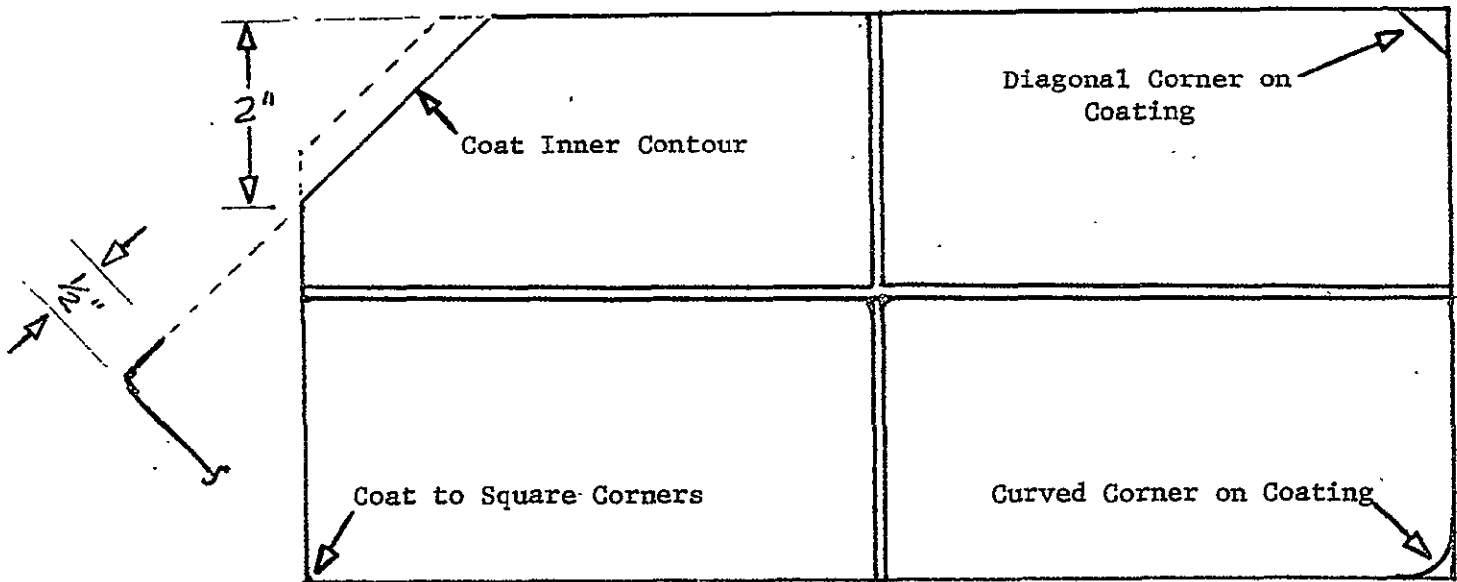


FIGURE 2 TRW THERMAL VACUUM TEST ARTICLE, 6061/Ag-TEFLON

TRW would furnish Ag-Teflon/585 adhesive in 2-3" wide tape. Schedule calls for test to begin before the end of September 1973 with temperatures to range from +40°F to -200°F for approximately 2000 cycles. TRW wants a second article coated with Vought supplied silver-Teflon/P-223 adhesive.

(b) Asked if Vought would work to a specified number of blisters in the silver-Teflon per unit area.

(c) TRW is forwarding the thermal vacuum test articles to: R.J. French, Unit 2-53002, Mgr., Environmental Control Group, LTV Aerospace Corp., P.O. Box 6267, Dallas, TX 75222.

(d) Next week TRW is sending the drawing of the heat pipe radiator, full scale, that they want coated in mid-November.

4 September 1973: Paul Mock, TRW, wants only the 6" x 12" panel coated with silver-Teflon/P-223 adhesive. Sheldahl is unable to supply the silver-Teflon/585 adhesive. TRW may be interested in testing our existing 9" x 10" 585 panel.

11 September 1973: Paul Mock, TRW, is waiting on detailed drawing on the heat pipe radiator panel. Mock, after consultation with NASA/JSC, decided to use P-223 adhesive on the 6" x 12" thermal vacuum test element and the flight hardware heat pipe radiator.

12 September 1973: TRW mailed the 6" x 12" thermal vacuum test element to R. E. Coats, Unit 2-63000, Contract Administration, Vought Corporation, P.O. Box 5907, Dallas, Texas 75222.

17 September 1973: Bill Jacobi, Sheldahl, advises that Ag-Teflon/P-223 adhesive is now a Sheldahl standard product, G404300; Ag-Teflon/585 adhesive is Sheldahl G404200. Vought asked Jacobi for the type of release liner that is supplied by Permacele on P-223 adhesive. Jacobi advised that skived TFE Teflon is the release liner used with 585 adhesive.

18 September 1973: Bob Geuting, DuPont, advised that Freon 21 was a better solvent than the other fluorocarbon liquids when asked about potential F-21 spill damage on Ag-Teflon. F-21 has no short term effect, i.e. from casual spills, on FEP Teflon film, Type A. F-21 is not classed as a commercial product by DuPont since the amount produced is less than 10,000 lb/year. F-21 is considered a "large amount" by DuPont since between 1000 lb. and 10,000 lb/year is produced. Freon E-2 is considered experimental, due to production of less than 100 lb/year.

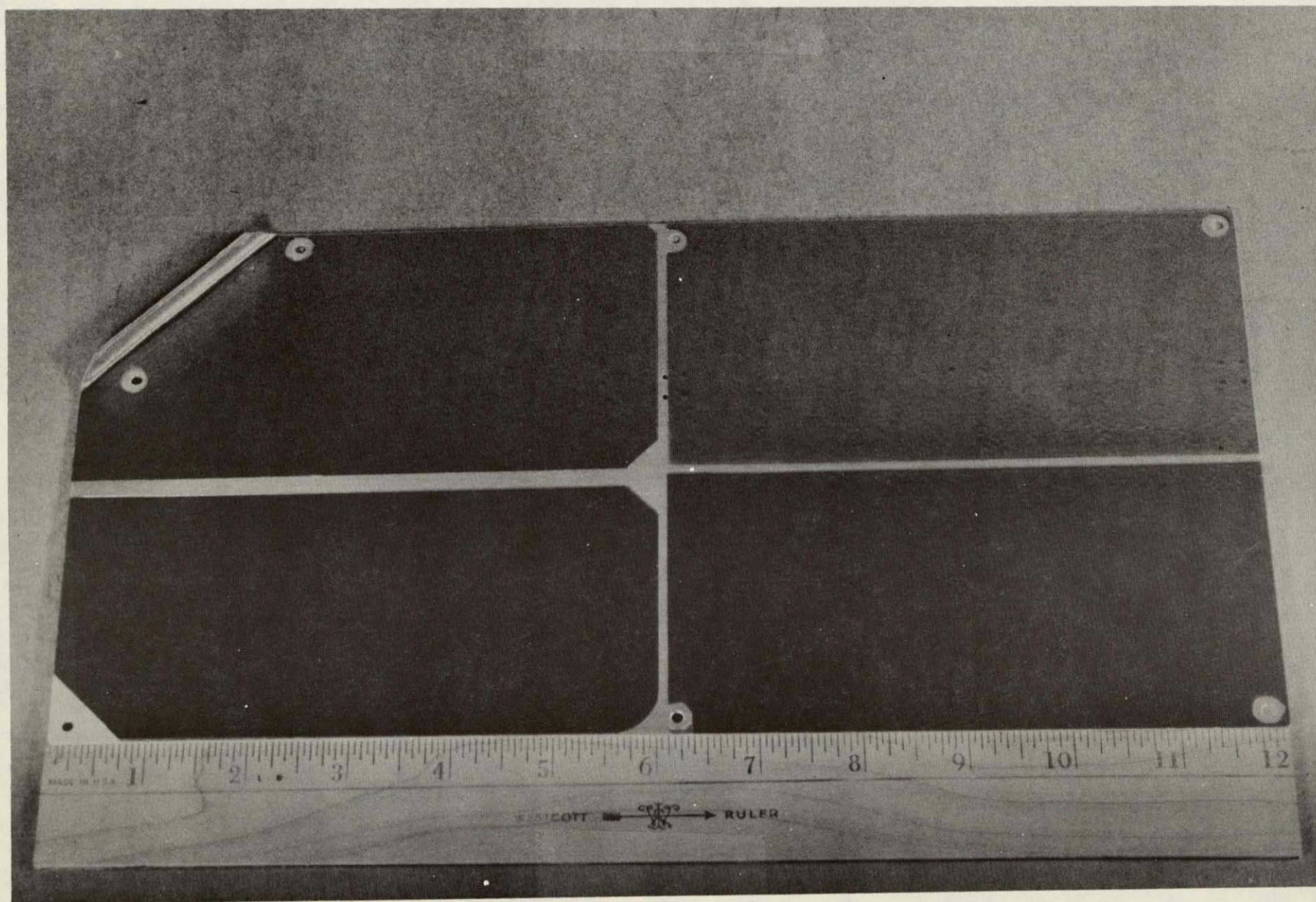
The F-21 must be dry or corrosion problems can develop. The chloride ions would break off by hydrolysis reaction if the F-21 were wet, forming HCl; this could start corrosion.

21 September 1973: Paul Mock, TRW, called to advise that the thermal vacuum test element was machined to the -1 drawing, rather than the -2 drawing sent us to quote. TRW wants the test element coated per the -2 drawing as closely as possible.

24 September 1973: The thermal vacuum test article was shipped to TRW after coating with Ag-Teflon as shown in Figure 3.

26 September 1973: Called Paul Mock, TRW, to resolve these questions. The heat pipe radiator will be used on the Communications Technology Satellite which NASA/Lewis is building for the Canadian Government Aerospace Agency. TRW is sending additional drawings next week which will have cutouts thru the Ag-Teflon so the attachment screws will be flush against the aluminum radiator. TRW also wants 6061- "Tee" section extrusions with jogs and cutouts coated with Ag-Teflon. NASA/Lewis must approve the coating process; Vought will submit the process directly to Lewis, rather than going thru TRW.





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FIGURE 3. Coated thermal vacuum qualification test article for the heat pipe radiator of Communication Technology Satellite. Dark areas are Ag-Teflon with overlay.

22 October 1973: G. Bourland, Vought Senior Specialist/Adhesive Bonding, stated that silicone adhesives of the type used in P-223 and 585 have excellent resistance to fatigue damage.

24 October 1973: Bob Coats, Vought Contracts Administration, advised that TRW wanted both sides of the 21" x 50" heat pipe radiator coated with Ag-Teflon.

6 November 1973: A Revised Statement of Work from TRW was received that reflects numerous detail design changes on the coating pattern for the heat pipe radiator for CTS.

12 November 1973: Talked to Bill Jacobi and Gene Hildreth, Sheldahl, concerning vibro-acoustic damage susceptibility of Ag-Teflon. Sheldahl data shows no changes in Al-Mylar with mass and adhesive similar to Ag-Teflon. Sheldahl's position is that the mass of Ag-Teflon is too low for large stresses to develop due to dynamic loading.

14 November 1973: Vought bids the CTS heat pipe radiator coating job.  
29 November 1973: Paul Mock, TRW, drops rework, testing, and marking requirements from the heat pipe radiator coating work.

14 December 1973: Wayne Slemp, NASA/Langley reports that National Metallizing is a low level competitor to Sheldahl on manufacture of aluminum on Mylar. Slemp has run Tefzel in UV exposure test and reported degradation to a gold color like polyethylene after 500 hours of exposure.

17 December 1973: Jacobi, Sheldahl, advises that the Northfield, Minnesota Advanced Products operation is on 1½ shift operation to produce metallized thin films.

18 December 1973: Calling Keith Blackmer, Rockwell International to verify that testing and evaluation of Ag-Teflon was in progress. A material spec is being prepared for Ag-Teflon; no testing to study size of strips, installation techniques, or refurbishment techniques is underway.

RI is releasing drawings with Ag-Teflon on the cargo bay doors at present.  
refurbishment techniques.

3 January 1974: Ike Spiker and Steve Jacobs, Non-Metals Section, SMD, NASA/JSC, visited Wayne Slemp, NASA/Langley. NASA does not have an NDT method to verify the Ag-Teflon bond for Shuttle Orbiter flights. NASA recommends sampling both ends of

a Ag-Teflon roll. Application of Ag-Teflon to aluminum structure by vacuum only should be investigated. Slemp agrees to perform thermal-vacuum screening tests for NASA/JSC on 585, P-223, and urethane adhesives with new catalyst systems not containing the potentially carcinogenic MOCA. He can test six 4" x 8" coupons simultaneously at -300°F in hard vacuum. Slemp, Langley, has just awarded a materials improvement contract to Sheldahl, primarily aimed at Ag-Teflon problems. A study is planned of (a) gold vs Inconel protective layer for the silver, (b) embossing the Teflon to reduce surface specularly, (c) use of Type C vs Type A Teflon for improved bonding characteristics, and (d) a lower tack coverlay. JSC will depend heavily on Slemp, Langley, for Ag-Teflon testing. Outgassing requirements for Shuttle are presently 0.1% VCM and 1.0% TML. No problem is anticipated with Ag-Teflon since only the edges of large sections, typically 4" wide x 44" long, are exposed.

9 January 1974: Called Wayne Slemp, NASA/Langley, concerning 467 adhesive for Ag-Teflon; Slemp does not recommend 467 if cryogenic exposure is likely.

14 January 1974: R. J. French, and M. W. Reed, Vought talked to Dr. Bruce Marcus, TRW in reference to the TRW request for a quote on three sets of CTS heat pipe radiator hardware. TRW is afraid the Vought price will escalate during the year between the first, second, and third ship sets of deliverables. Vought will take up the question with our contracts people.

15 January 1974: Paul Mock, TRW, called with test results. 1000 thermal-vacuum cycles were run on Sheldahl 4019 Ag-Teflon with 467 adhesive. Four 2" x 4" panels were exposed +150°F to -250°F. The test also included 3 years equivalent electron exposure simultaneously. The anticipated coldest on-orbit temperature will be -185°F in a synchronous orbit. The tape was outgassed 6 hours after removal of the release paper at ambient. Cure was 150°F for 6 hours without vacuum bag. The orientation in the test chamber was up. One side only was coated of the 2" x 4" test articles. TRW will send a paper, when available, which covers this work. Irwin Zelman, TRW Systems, Inc., One Space Park, Redondo Beach, CA 90278, has performed this testing.



23 January 1974: Paul Mock, TRW, wants to either paint or Ag-Teflon coat the heat pipes and saddles. TRW will perform in-house due to complexity. TRW will decide by end of January if LTV is to coat the heat pipe radiator.

31 January 1974: Paul Mock, TRW, with Bob Coats, Vought, on the line called to award the heat pipe coating job to Vought. TRW wants three/<sup>other</sup>parts, 3" x 3" with a slight curvature and 4 holes, to be coated on one side; three ship sets of three parts each are required. TRW is coating the heat pipe in-house, Vought will furnish the Ag-Teflon for the total job. A set of assembly drawings will be furnished so that mating surfaces and orientation can be determined.

7 February 1974: Receive "Tee" section drawing change from Bob Coats, Vought, on TRW heat pipe coating work.

8 February 1974: TRW asked Vought to order two 2 -inch wide rolls of G404302 (P-223) Ag-Teflon from Sheldahl.

11 February 1974: Paul Mock, TRW advised that the Ag-Teflon compound curve areas of the joggles in the "Tee" sections could be relieved by slitting to improve the fit. Mock said a purchase order was being "walked thru" to buy the Ag-Teflon from Vought.

25 February 1974: Phil Sheps, Vought/JSC called for Ag-Teflon test definition for SMD/NASA/JSC. SMD plans to design a test profile for NASA/Langley to follow for evaluation of Ag-Teflon. Temperature cycle to be -270°F for one-four hours to assure reaching steady state, followed by +250°F with a one hour soak, The up-ramp should be 6°F/minute; the down-ramp should be 1°F/minute with the number of cycles to be defined by projected Orbiter missions. Vought prepared a memo, 74-IM-11, outlining the suggested testing.

28 February 1974: Vought receives the TRW purchase order for the CTS heat pipe radiator coating package. Bob Coats, Contracts Admin., Vought, asked that the Ag-Teflon be ordered immediately. Drawings of the radiator and Tee-sections that detail the coated areas are shown in Figures 4 and 5, respectively.

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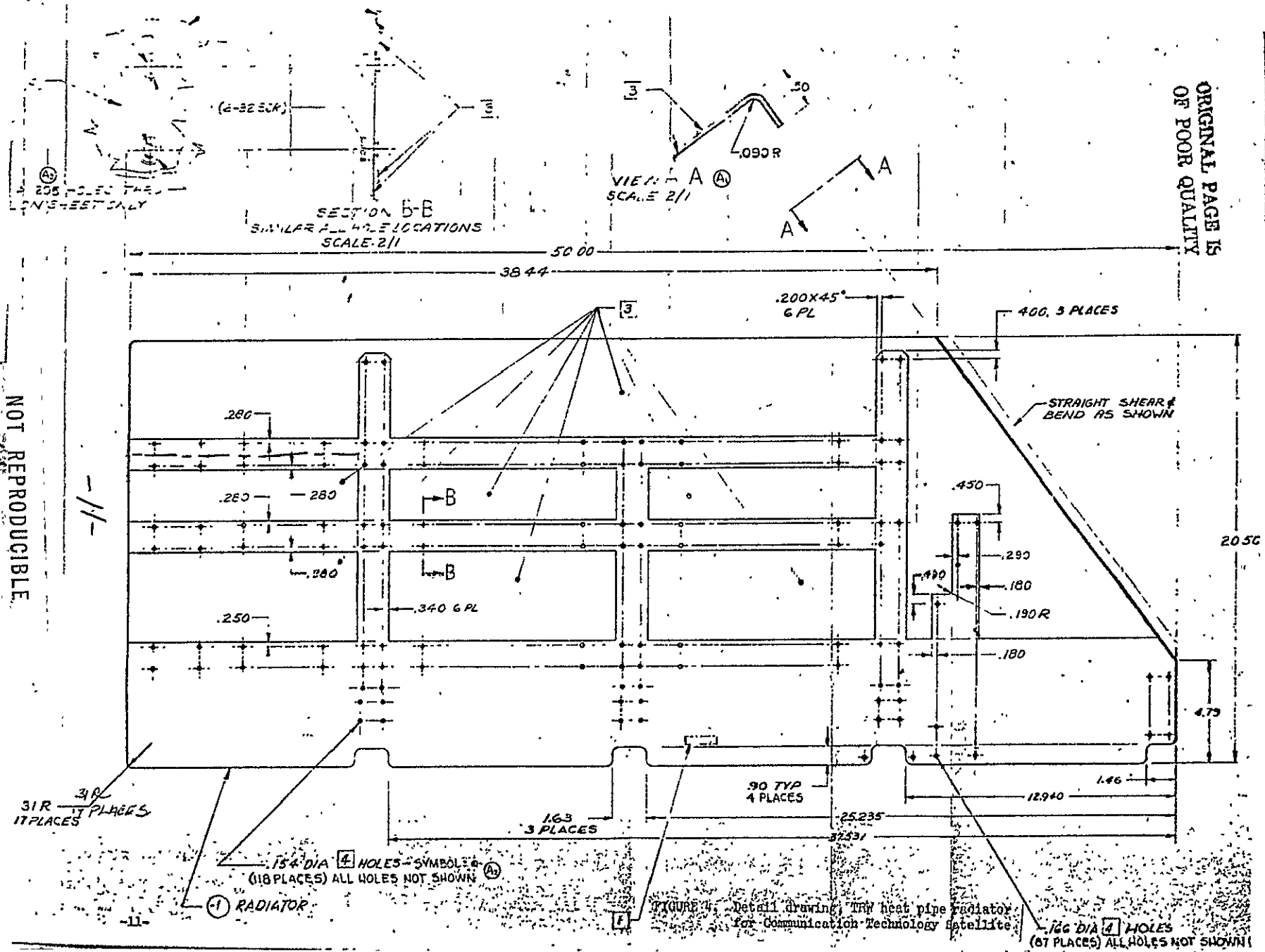


FIGURE 4. Detail drawing of heat pipe radiator for Communication Technology Satellite



1 March 1974: Paul Mock called from TRW with these questions: (a) When is the Ag-Teflon scheduled from Sheldahl? TBD (b) When will the first ship set be coated? Approximately two weeks after receipt of detail parts from TRW and Ag-Teflon from Sheldahl. (c) TRW adding a 1.6" x 13.5" area to be coated on the heat pipe radiator, -265. (d) Vought should retain one-half of a 2-inch roll before shipment to TRW for coating this and other projected changes. (e) Drawings dimensioning the changes to the -265 radiator and the -258 "Tee" section will be sent with the detail parts. (f) TRW is having problems with their buyer putting in unnecessary conditions. (g) TRW will call with the shipping date and waybill number of the details to be coated. (h) Test coupons for the Ag-Teflon are only required on ship sets 2 and 3. (i) Ship set 1 is for engineering fit check only.

4 March 1974: TRW states that 4.61 inches in the widest individual panel to be coated on the heat pipe radiator. The purchase order was placed for the TRW Ag-Teflon. Widths of 1 inch, 2 inch, and 4.65 inch were ordered.

5 March 1974: Dave Rosen, CSD, NASA/JSC asked for Vought's opinion on changing the soak time at temperature to 5 minutes and the up-ramp to 10-20 minutes total time. Vought agreed if each specimen was individually instrumented and monitored.

20 March 1974: Bob Coats, Vought, relates that NHB5300.4(1C), a quality control specification, has been imposed on Vought by the TRW buyer on the heat pipe radiator program. Coats asks that Engineering resolve this matter with Paul Mock, since it was not in the Vought bid.

20 March 1974: Paul Mock, TRW, shipped the first ship set of detail parts for coating on 14 March in one carton, Attention: R.E. Coats. Mock stated the NHB 5300.4(1C) is not required. NHB5300.4(1C) gives a general plan for maintaining quality control procedures and establishing Material Review Board activities. Mock will attempt to have NHB5300.4(1C) removed as a requirement on the Vought heat pipe radiator coating work.

20 March 1974: Jacobi, Sheldahl is checking to advance the scheduled shipping date of 5 April on the Ag-Teflon for TRW.

21 March 1974: R.J. French, Vought Radiator Program Manager, asked for a preliminary material specification for Ag-Teflon so Sheldahl can bid against it in

the Orbiter Radiator proposal to Rockwell International.

22 March 1974: Sheldahl will ship two rolls of 2-inch Ag-Teflon/P-223 within one week. The 4.65" laminate will be shipped later after receipt of special Teflon and coverlay. One roll of 4 inch width can be shipped immediately.

28 March 1974: TRW orders that Vought coat the first ship set with 4 inch Ag-Teflon rather than waiting on the 4.65 inch material. In addition, TRW asked that the 2- inch material be trans-shipped to TRW as soon as possible.

28 March 1974: Roger Otos, R.I., mentioned that Keith Blackmer has been moved to have cognizance over surface finishes and electrical materials, leaving thermal control coatings to be covered at R.I./Downey by Otos. The thermal control coating in tape form was applied to the Apollo Command Module in 1-inch, 2-inch, and 4-inch strips. Wider strips of the tape were harder to apply without wrinkling. A summary of the adhesives and widths of Ag-Teflon used in the Modular Radiator testing of July, 1973, was given to Otos. In addition, Otos requested Bill Morris' telephone number at NASA-JSC and the Sheldahl specification numbers for Ag-Teflon and Al-Teflon:

G404300 = 5 mil FEP/Ag/Inconel/P223

G404200 = 5 mil FEP/Ag/Inconel/585

G404400 = 2 mil FEP/Ag/Inconel/585

G404500 = 5 mil FEP/Al/585

28 March 1974: Sheldahl shipped Ag-Teflon one 1-inch roll x 108 feet long, and one 2-inch roll x 80 feet long by air freight.

1 April 1974: Sheldahl shipped two rolls of Ag-Teflon for the TRW coating work on 29 March 1974.

3 April 1974: Paul Mock, TRW, asks that Vought measure the length of the 2-inch Ag-Teflon being shipped to TRW. Vought advises Mock that we will not include compliance with NHB5300.4(1C) as it was not bid and the Quality hours to support it would be large. Vought specifically asks that it be deleted for this job.

3 April 1974: TRW, Dr. Bruce Marcus, was advised that the -14 "Tee" section needed a cut-out to meet the drawing requirements. The -15 "Tee" section was 1/8" too long. Marcus was to have Paul Mock call with fixes.

3 April 1974: Copies of the Sheldahl specifications relating to the components of Ag-Teflon coating were requested from Bill Jacobi.

4 April 1974: Vern Reineking, TRW, will have Mock send a copy of the TRW Ag-Teflon specification C 125741.

8 April 1974: Paul Mock, TRW, advised Vought to use Ag-Teflon to Sheldahl specification GT404302 on the heat pipe radiator components.

10 April 1974: Vought shipped the coated, engineering fit check, heat pipe radiator assembly to TRW in two boxes. TRW advised that the radiator is mandatory to the CTS operation. No redundant system for the heat pipe radiator exists on the spacecraft. Two passive heat rejection paths exist. A photograph of the CTS and a copy of the Ag-Teflon specification C125741 will be sent. The Canadians are building the spacecraft. NASA/Lewis is engineering the spacecraft. TRW builds only the heat pipe radiator system. The heat pipe cools the electronics and the traveling wave tube. The TRW effort on heat pipes is an add-on to the NASA/Lewis engineering effort to solve a design level heat rejection problem. TRW does not plan to clean the Ag-Teflon after removal of the coverlay prior to launch. The heat pipe radiator is shown in Figures 6 and 7.

10 April 1974: Ask Sheldahl for cost impact of solar absorptance  $\leq 0.06$  and emittance  $\geq 0.8$  on the cost of G404302 Ag-Teflon, Sheldahl was also asked to provide an improved release cloth, film, or paper which left lower residue on the silicone adhesive.

11 April 1974: Jacobi, Sheldahl, made these comments on the instruments used to measure optical properties of the Ag-Teflon. The Sheldahl, Beckman DK-2A reads slightly high, 0.07-0.08, on a first surface aluminum mirror versus 0.084 on a NASA Goddard standard instrument for solar absorptance. The Sheldahl, Lyons Emissometer reads low, 0.77 in normal emittance, versus Goddard measured values of 0.81 - 0.83 using a Gier-Dunkle DB-100 portable infrared spectrometer. The Gier-Dunkle mobile solar reflectometer measures relatively low on specular samples like Ag-Teflon, but very close on diffuse samples like paints. Vought will check to verify that TRW



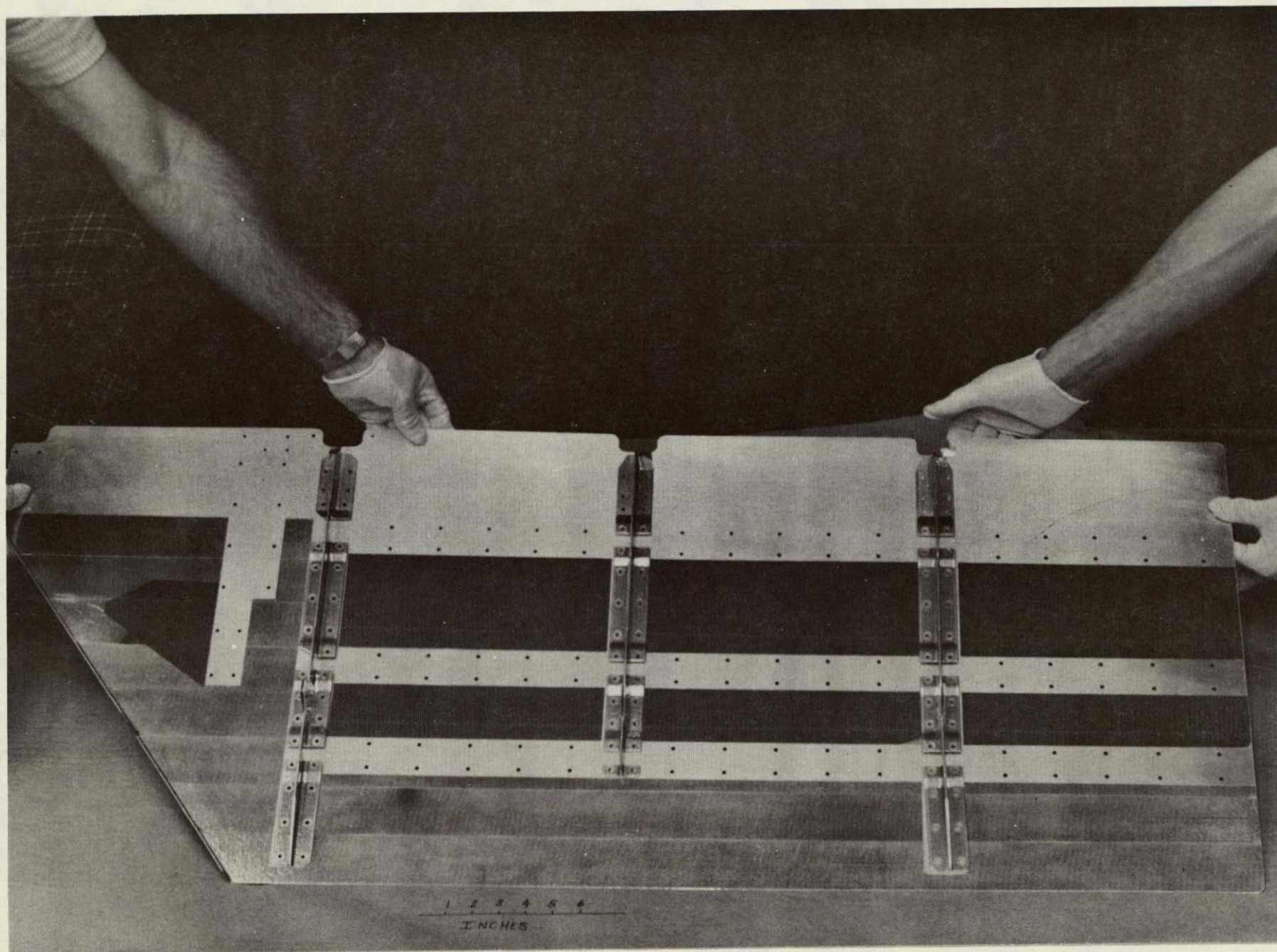
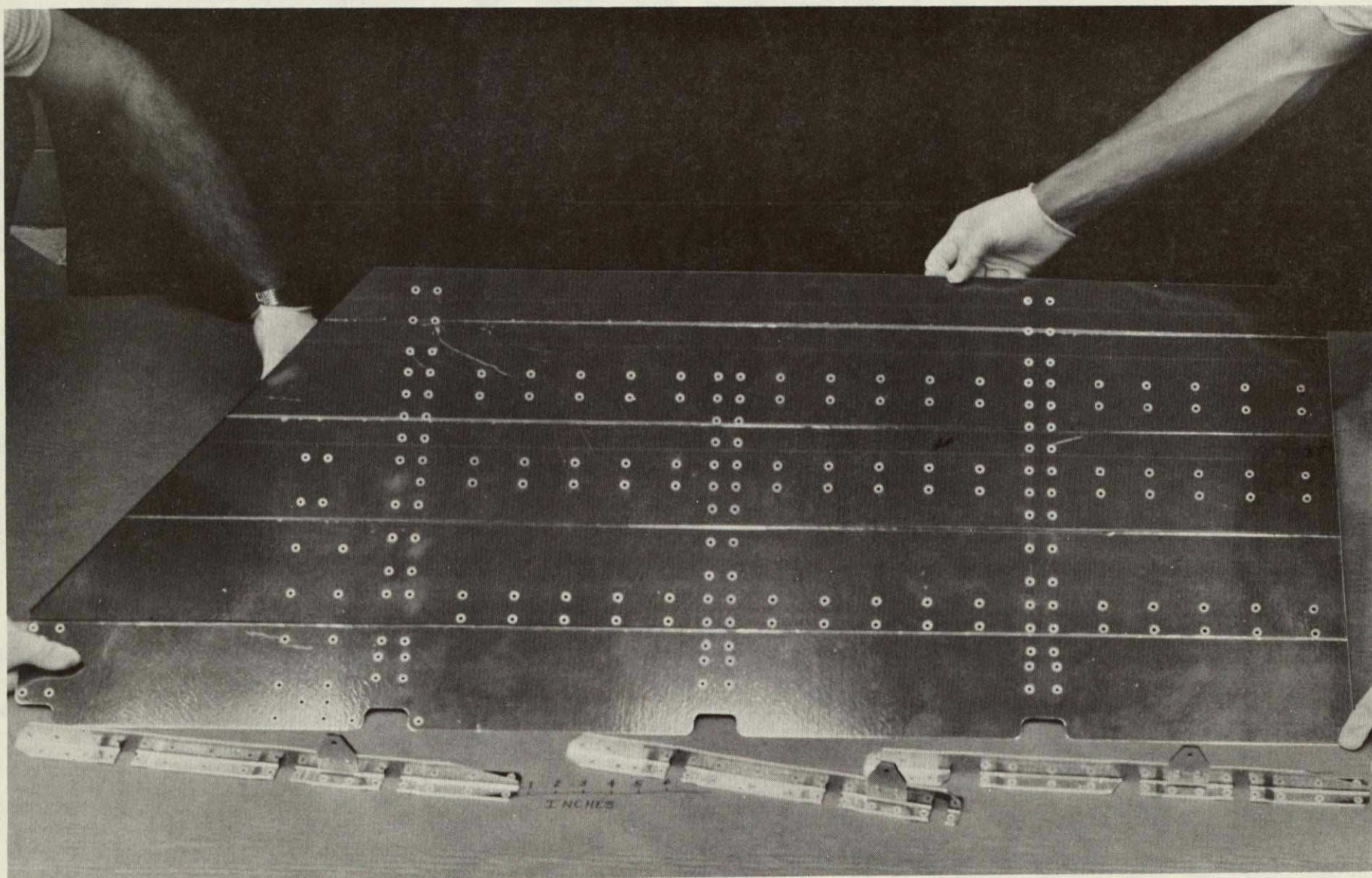


FIGURE 6. Heat pipe radiator for Communications Technology Satellite/with coated Tee-sections in position for assembly. Dark areas are Ag-Teflon with coverlay.

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FIGURE 7. Coated Heat Pipe radiator, reverse side, for CTS and coated structural Tee-sections. Note removal of Ag-Teflon, light holes, for enhancing thermal conductivity between heat pipe attachment bolts and radiator.



will accept the Sheldahl measured optical properties. Sheldahl has not received the wide P-223 to be used in manufacture of the TRW 4.65 inch wide Ag-Teflon. Sheldahl obtains the P-223 from Permacel with the crinoline cloth release liner; they will ask for schedule and cost impact of changing release liners at Permacel.

18 April 1974: Several topics relating to Ag-Teflon for the Orbiter radiators were discussed with Sheldahl. Sheldahl will attempt to upgrade the quality of coverlay application, specifically the wrinkles and tattered edges. Selective shipment is the only method presently available for obtaining lower absorptance and higher emittance. RI must call out a measuring technique for absorptance of  $\leq 0.06$ . A specular sample from NBS is used as the standard in the DK-2A. The Lyons Emmisometer measures essentially normal emittance. A standard batch of Ag-Teflon consists of 40 square feet maximum, with excellent reproducibility from end to end of the batch. The FEP Teflon is spiral wound on a drum in the desired width to make 40 square feet. Cleaning of the Teflon is best accomplished by an alcohol wipe with a soft cloth. FEP film will not work as a release film for 585; skived TFE Teflon is only successful release film to date. High molecular weight polyethylene film was not useable. Slomp at NASA/Langley can evaluate a lower tack version of the 585 if Sheldahl will compound. Jacobi has a paper on metal adhesion to plastic films, J. Applied Vacuum Science, V. 11, #1, Jan-Feb. 1974 and he will forward a copy. Skived TFE might cause higher tack on P-223 than the crinoline cloth. Jacobi wants the raw data from Jacobs, NASA-JSC, on the optical measurements after the thermal-vacuum test in July 1973.

19 April 1974: Inspection of the modular radiator panels revealed:

- (a) the pattern of the release cloth with the P-223 was carried over to the cured Ag-Teflon;
- (b) two small areas, approximately 1 square inch each, of separation exist between the P-223 and the aluminum radiator;
- (c) removal, peel-back, or lift-off of 585 during application caused severe crazing (cross-hatched pattern) of the Ag;
- (d) no separation between 585 and the aluminum radiator was noted.

22 April 1974: Optical properties data taken by Jacobs, NASA-JSC after the July 1973 modular radiator test was sent to Jacobi, Sheldahl.

23 April 1974: Sheldahl was contacted regarding delivery of the remaining Ag-Teflon for the TRW CTS program; no date was promised.

23 April 1974: Jim Williams, Project Engineer on Radiator Programs, Vought, asks that 50 square feet of Ag-Teflon be ordered for element tests on the JSC Modular Radiator contract. Engineering should trade costs and technical advantages (weight) of 585 versus P-223. Two 4 inch rolls/585 @ \$199/inch of width = \$1592. Two 4 inch rolls/P-223 @ \$193/inch of width = \$1545.

23 April 1974: Sheldahl, Jerry Maas, advises that the P-223 for the remaining TRW Ag-Teflon was shipped 15 April from Permacel. In general, Sheldahl can ship Ag-Teflon within one week after receipt of P-223 from Permacel. Jacobi will call back with projected shipping information on low tack 585, formulated to Vought requirements.

26 April 1974: Jacobi, Sheldahl called to advise that the low tack 585 would be produced by reducing the adhesive thickness from 1 mil to 0.7 mil and curing at a higher temperature to make the adhesive somewhat harder with a corresponding decrease in tack. Shipment of the remaining 2 inch and 4.65 inch tape for the CTS program will be made within one week.

30 April 1974: Two rolls, 4 inch width of Ag-Teflon with low tack 585 adhesive, were ordered.

3 May 1974: Marvin Rau, Permacel, recommends a silicone treated paper as a possible release liner for P-223. The cloth presently used is called: print cloth, cotton, heavily sized, off white. Permacel 257 or 423 Teflon tape/silicone adhesive has a typical silicone treated paper.

13 May 1974: Vought begins 60 day radiator study contract with Rockwell International. Several Ag-Teflon related tasks will be addressed.

13 May 1974: Sheldahl was contacted for current schedule of shipment of the remaining 2 inch Ag-Teflon for the TRW/CTS program.

15 May 1974: TRW advised that the engineering fit check hardware for heat pipe radiator arrived in perfect condition. The details have been assembled; the fit is good. CDR was held last week; TRW is awaiting go-ahead, possibly next week. The remaining two ship sets will be shipped to Vought for coating within two weeks of go-ahead. TRW may slip the shipping one week to accommodate late design changes. Current schedule is:

- (a) 15 July 1974: Vought shipping coated hardware to TRW;
- (b) 1 August 1974: TRW delivery to NASA/Lewis of the first heat pipe radiator assembly;
- (c) 1 September 1974: TRW delivery to NASA/Lewis of the second heat pipe radiator assembly.

22 May 1974: Dr. Bruce Marcus, TRW, stated that a high energy particle problem was revealed at CDR on the heat pipe radiator for CTS. High energy plasma environments on satellites in synchronous orbit caused 10 - 20 KV negative charges to develop in capacitors. TRW may ask Vought to consider grounding the silver (Ag) layer of the Ag-Teflon to the aluminum substrate. Suggestions to accomplish this were offered as follows: (a) dust conductive metal powders such as silver or copper on the substrate prior to adhesive application, (b) bond aluminum straps between the Ag layer and aluminum substrate, (c) remove a small area of the adhesive and replace with silver conductive adhesive such as Electrofilm 1777 for which Vought has a specification. Marcus anticipates that 2 grounding devices would be required on each piece of Ag-Teflon larger than 10 square inches with only one being required on each individual area less than 10 square inches. Approximately 40 - 50 grounding contacts are projected per vehicle.

23 May 1974: Jacobi, Sheldahl, was asked for specular data on Ag-Teflon, specifically for angular reflectance at low incidence angles. Jacobi has looked at embossed FEP Teflon for Slomp at NASA/Langley. About 90% of the return is specular with conventional Ag-Teflon. Only 40% of the return is specular after embossing. The Teflon film is embossed on each side before metallizing.

28 May 1974: Ag-Teflon/P-223 was determined to weigh 0.076 lb/square foot. The 1 mil Kapton used as a carrier weighed 0.00736 lb/square/foot.

3 June 1974: The RI sonic fatigue test specimen, bonded honeycomb with tubes, 45 inch x 81 inch x 1 inch, was coated with Ag-Teflon on one side.

4 June 1974: Vought recommended storage of the coated radiators for ten years life per:

- (a) Radiator to remain in the shipping container.
- (b) The container to be a sealed metal can, evacuated by mechanical pump vacuum to 10 microns absolute pressure.
- (c) The metal container to be backfilled with inert, dry gas to a positive pressure of 25 psig.
- (d) Use a combination vacuum-pressure gauge to monitor internal container pressure. Periodic external inspection would confirm the internal pressure.
- (e) If the pressure falls below 15 psig, re-evacuate the container and backfill with the inert, dry gas.

5 June 1974: Vought remains one 2 inch roll short of TRW coating requirements. Sheldahl advises that the P-223 from Permacel is back ordered for two months. Paul Mock, TRW, indicates a capacitance discharge problem exists with the Ag-Teflon coated heat pipe radiator for CTS. Vought asks for the basic data that led to discovery of the problem.

14 June 1974: Paul Mock, TRW, gave the following elaboration on the capacitance discharge phenomena on CTS, which is now considered a grounding problem. The grounding problem, i.e. a suspected static charge built-up in the Ag-Teflon, was not an original design criteria for the CTS. TRW submitted a proposal on grounding recently to NASA/Lewis that suggested grounding the Ag-Teflon using the same criteria that requires the second surface mirrors on CTS to be grounded. An area twice as large as the heat pipe radiator is coated with Ag-Teflon as a passive Thermal Control Coating on CTS. The passive areas of CTS are being coated with G401900 Ag-Teflon with 467 acrylic adhesive.

NOTE: Vought thermal-vacuum tests on Ag-Teflon/467 in 1972 revealed loss of adhesion in cryogenic temperature excursions.

TRW anticipates a reply within the immediate future, possibly one week, on the grounding proposal. The details are fabricated for the two remaining ship sets of heat pipe radiator hardware. TRW will forward them to Vought if NASA decides the grounding is to be funded under the TRW contract. Both classified, TRW-built satellites and unclassified satellites in geosynchronous orbits into Earth's umbra have had valves actuated and telemetry cycled on and off. These unscheduled events are blamed on discharging of ungrounded surfaces on the spacecraft. Grounding of major surfaces has helped the problem on the most recent satellites. No satellites in orbit (Mock's opinion) are fully grounded to Mock's knowledge.

8 July 1974: Roger Otos, RI, asked if Vought had selected a preferred adhesive system for Ag-Teflon. Two were still under active consideration at the time. Otos suggested that absorptance measurements are unreliable and non-reproducible. The portable Gier-Dunkle emittance technique is reliable, however, RI does not have a good, portable technique for measurement of solar absorptance. NASA/Huntsville has reported development of an instrument "in-house" for absorptance measurements. Jacobi, NASA/JSC, is sending the Ag-Teflon optical properties specimens to NASA/Huntsville for evaluation with their instruments. Otos would like a repair technique called out in the Ag-Teflon process specification. RI has specimens at NASA/JSC for determination of solar absorptance; lengthy delays have occurred in getting data from JSC.

9 July 1974: Paul Mock, TRW reported that 100% grounding will not be used on the Ag-Teflon of CTS. The size of individual pieces of Ag-Teflon will be limited to 200 square centimeters (31 square inches) to minimize static charge accumulation. TRW authorizes Vought to lay up the Ag-Teflon in the preferred pattern, followed by slitting to 200 square centimeters maximum area prior to cure. The two ship sets of heat pipe radiator detail will be shipped for coating by 18 July 1974.

10 July 1974: Gene Hildreth, Sheldahl, shipped on 9 July one 2" roll and one partial roll, 1 inch wide x 15 feet in length. The remaining item on the order is 39 feet of 2 inch Ag-Teflon.

15 July 1974: Vought advised TRW that a three day delivery slide is anticipated due to the requirement for 200 square centimeters maximum area allowed for individual pieces of Ag-Teflon on CTS.

16 July 1974: Prepared a ROM estimate for coating each side of the self-contained Heat Rejection Module (SHRM). Four panels, 94 inch x 94 inch 6061 aluminum make up the SHRM. Eight rolls of 4 inch and ten rolls of 3 inch Ag-Teflon are required.

18 July 1974: Telecon with Hildreth, Sheldahl, to expedite shipment of the remaining 39 feet of 2 inch Ag-Teflon.

18 July 1974: Sheldahl wins contractor of the year award from the Martin Co. for the Viking Bioshield.

22 July 1974: Jerry Maas, Sheldahl, will ship the remaining 39 feet of 2 inch Ag-Teflon as soon as possible.

2 August 1974: Helsa Servis, Lockheed/Sunnyvale (LMSC) called to discuss cure problems with 467 adhesive on Al-Teflon. LMSC cures the Al-Teflon at 165°F for 16 hours in air without vacuum blanket. Thermal vacuum testing consists of cycling between +280°F and -230°F for two hours with a five minute soak at each temperature. The 4" x 6" specimens are oriented up in the vacuum chamber. The Al-Teflon is applied in 1 inch strips. LMSC has coated hardware with Al-Teflon/467 in 19 inch wide sheets. Servis reported that George Epstein, Aerospace Corp., has used 2 mil Ag-Teflon/467 successfully through 1000 cycles of -300°F to +70°F. LMSC reports the shrinkage is less than 1% on the Al-Teflon after cure.

5 August 1974: Slomp, NASA/Langley, reported that 585 and P-223 have TML of approximately 4%, too high for use on Orbiter.

8 August 1974: Paul Mock, TRW, advised that the two sets of heat pipe radiator hardware will be mailed the week of 12 August with two additional cut-outs required for holes. The drawings and E.O.'s that reflect all the latest changes - 23- will be included in the shipping crate with the hardware.

19 August 1974: Paul Mock, TRW, shipped the CTS radiator panels 19 August. TRW must ship the first ship set to Lewis 1 October. Vought should ship coated hardware to TRW by 15 September.

19 August 1974: Vought called Sheldahl for delivery schedule of the remaining 2" Ag-Teflon.

23 August 1974: The CTS heat pipe radiator details arrive; no optical properties coupons are included. Sheldahl was contacted again to obtain the 39 feet of Ag-Teflon.

29 August 1974: Harold Howell, Vought Project Engineer, Modular Radiator Contract, NASA/JSC, asked for ROM quote on coating with Ag-Teflon:

- (a) both surfaces of a forward Orbiter radiator of bonded honeycomb construction;
- (b) the concave surface of an aft Orbiter radiator of bonded honeycomb construction;
- (c) the concave surface of two simulated payload bay doors/ribs of aluminum sheet construction;
- (d) 33 rolls of silver-Teflon are required to coat the above hardware with no contingency.

5 September 1974: Sheldahl can deliver 50% of the anticipated 33 roll order, 4 inches wide, in 5 weeks if Vought low tack 585 is specified as the adhesive. The remaining 50% would be delivered in 4 more weeks.

9 September 1974: Sheldahl was contacted for specification call-out for the low tack 585.

13 September 1974: Mock, TRW, advised that the engineering fit check set of the Ag-Teflon coated heat pipe radiator was used as a test article and has

completed an ambient temperature vacuum test. Athermal vacuum test to -200°F will be run on this hardware within two weeks.

24 September 1974: Steve Jacobs, NASA/JSC, sent the optical properties coupons from the RI 60 day radiator design study to NASA/Huntsville for measurement. Huntsville has returned the unreduced data to Jacobs who is forwarding it to Vought for reduction when time and budget can be found. Jacobs calculated 12.4 lb. of Ag-Teflon/radiator surface, 11.5 feet x 14.5 feet.

25 September 1974: Wayne Slemple, NASA/Langley, wants to change to 40-100 thermal cycles for Ag-Teflon evaluation between -325°F and +300°F with 10 minute larger upramps and 15 minute larger down ramps. Application of Ag-Teflon by heated, Teflon-coated roller was discussed. P-223 looks promising. Temperatures range between 250°F and 350°F. Mystic 7366 tends to blister and release from the substrate. Acrylic 467 has about 50% failed area after test. Polyester 46970 performs well between +300°F and -140°F; it fails at -150°F in Langley thermal cycling.

30 September 1974: Sheldahl performs a climbing drum peel test on Ag-Teflon, not the ASTM D-903 which is 180° peel. Jacobi feels the 180° peel is too severe for Ag-Teflon. Sheldahl wants aluminum test coupons for cured tests to be 0.040 inch minimum -0.063 inch maximum for stiffness. A leader, 4 inch to 8 inch length, should be discarded from the end of each roll prior to sampling for test.

9 October 1974: Bill Morris, NASA/JSC, discussed material quantity requirements for the Ag-Teflon for the combined radiator-payload bay door cavity testing scheduled in early 1975 in chambers A and B at SESL/JSC.

10 October 1974: Dave Rosen, NASA/JSC, called for shipping address of Vought for drop-shipment of the GFE Ag-Teflon.

14 November 1974: Vought Engineering estimated by ROM the Ag-Teflon coating of the "Tee" section ribs for the inside of the simulated cargo bay door that Vought is fabricating for NASA/JSC cavity testing.

27 November 1974: Analysis of the latest design for the radiator-door cavity test articles showed that forty-two rolls of Ag-Teflon should be ordered for the combined test. This will allow a modest contingency to re-coat one typical radiator or door surface.



27 November 1974: Paul Mock, TRW, reported that the peel strength of the Ag-Teflon control specimens measured 2.7 lb/in (average of 6) with a spread between 2.44 - 3.26 lb/inch at a loading rate of 12 inch/minute. A thermal-vacuum test of the 1st ship set of heat pipe radiator hardware at NASA Lewis was successfully passed. Thermal extremes were -130°F to +120°F with iR panels as environment; panel orientation was horizontal with the reverse side, as seen in Figure 7, down. A thermal-vacuum test at NASA Goddard with solar simulation was scheduled. Environment ranged from -220°F to +120°F with vertical panel orientation. The 6" x 12" test panel detailed in Figure 2 showed no change after 15 cycles to -250°F with vacuum in test at NASA/Lewis.

2 December 1974: Bill Jacobi, Sheldahl, transfers to Sales Manager, Materials Group. Gene Hildreth is promoted to Manager - Thin Films, Advanced Products Group. Hildreth has technical responsibility for aerospace thin films, laminates, and tapes. Gene Hildreth reports to Harvey Henjum. The price of Ag-Teflon is unchanged. Thirty four rolls of 4-inch Ag-Teflon/Vought low tack 585 adhesive were ordered by NASA/JSC for shipment as GFE to Vought.

3 December 1974: M.W. Reed, Vought, attended Flexible Metallized Films in Space Systems Symposium at Aerospace Corp., ElSegundo. The meeting was primarily a discussion of Ag-Teflon problems as encountered on unmanned spacecraft. Reed made an informal presentation of Vought test results from the past 2 years, which was well received.

The planned format was to be an informal round table discussion. The attendance of 71 engineers and scientists caused a more formal atmosphere to develop, similar to a national technical session. Five general discussion areas were outlined by David Robbins, who organized the meeting: 1) systems overview

2) spacecraft performance, 3) quality control and assessment, 4) application and bonding problems, 5) optical properties. Presentations were made as follows:

1) Systems Overview

- a) Dan Stafford, Aerospace, "Silver-Teflon on Deep Space Probe".
- b) Helsa Servis, Lockheed, "Testing Silver-Teflon".
- c) Dick Kerlin, TRW, "Flexible Materials Test Program". This contract resulted from the classified SAMSO RFP received in Spring, 1974.

2) Spacecraft Performance

- d) Bob McGregor, Boeing, "Degradation of Silver-Teflon".
- e) W.C. Beggs, TRW, "Static Discharge of Metallized Films and Insulation Blankets".

3) Quality Control and Assessments

- f) Les Goldstein, Aerospace, "Mechanical Tests for Metallized Films".
- g) Bill Jacobi, Sheldahl, "Manufacturing and Q.C. Problems with Metallized Films"

4) Application and Bonding Problems

- h) Fred Betts, NRL, "Bonding Ag-Teflon to Spacecraft".
- i) Joe Frey, NASA Goddard, "Application of Metallized Films to Satellites".
- j) Max Barsh, Aerojet Electrosystems, "Low Temperature Silvered Teflon System".

5) Optical Properties

- k) R. Robert, Aerospace Corp., "Bidirectional Reflectance of Crinkled Silver Teflon".
- l) J.T. Neu, General Dynamics - San Diego, "Diffuse Surface Silver-Teflon".

The viewgraphs used in the presentations will be copied and distributed to the attendees. Detailed notes on the papers and discussions are available from the writer. While numerous comments on each presentation were made, the paper (2e) on static discharge phenomena evoked considerable discussion. SAMSOS sponsored a meeting on static discharge in spacecraft several weeks ago; Wayne Schober of SAMSOS (213-643-0773) organized this meeting. TRW did not attend or know of the static discharge meeting.

19 December 1974: Dave Rosen, NASA/JSC, ordered 34 rolls of Ag-Teflon scheduled for 50% shipment by 30 December 1974. The remaining 50% will be shipped 10 January 1975. An additional 7 rolls will be ordered after 1 January 1975 on a different purchase order.

7 January 1975: Coating of heater panels for the simulated cargo bay door was started. The quality of the Ag-Teflon was relatively poor with many visual defects of types not previously seen. Tack of the 585 adhesive was widely variable.

7 January 1975: Vought reported to Dave Rosen that 17 rolls of the Ag-Teflon had arrived and that panel coating was underway.

8 January 1975: Sheldahl was notified that the NASA Ag-Teflon has:

- (a) entrapped bubbles in 585 adhesive, even when meticulous care is taken with layup.
- (b) adhesive may be outgassing after removal of the skived TFE release liner;
- (c) entrapped bubbles seem more severe in wrinkled overlay areas;
- (d) certain areas of Ag-Teflon seem "limp"; these must be removed from the panel before cure due to poor layup characteristics;
- (e) Sheldahl should consider a change in 585 formulation to that used in May, 1974, for the two roll order for Vought;
- (f) Sheldahl should consider, as a back-up position, changing the remaining NASA order to P-223.

10 January 1975: Vought explained the various problem with the GFE Ag-Teflon/585 adhesive to Harvey Henjum, Sheldahl.

13 January 1975: Gene Hildreth reports that the NASA 585 adhesive was prepared on the production roll laminator on a continuous basis, rather than the laboratory equipment used on the previous 585 orders. Sheldahl is varying solids content, thickness, and solvent content to get the low tack 585; they are having much trouble removing the solvent (probably toluene) since the skived TFE does not breathe. Retained solvent is probably causing the bubbling problem during layup and cure at Vought. Sheldahl does not have P-223 at present, but are waiting on material ordered 2 December 1974. Jerry Valley, Manager - Quality Assurance/Thin Films, will visit Vought on 16 January 1975 to see the problem first hand.

16 January 1975: Jerry Valley, Sheldahl brings different formulation of Ag-Teflon/585 for trial. It has 8-10 ounce/inch of peel strength versus 25 ounce/inch of first material. Vought prepares layup and cures in real time. The different formulation bubbles as badly or worse during cure as the material received in early January. Valley takes defective samples of both batches of 585 back to Sheldahl for evaluation.

17 January 1975: Rudy Krosche, Permacel, Princeton, New Jersey, advised that P-223 was not in stock. Delivery on P-223 would be scheduled for the end of February.

20 January 1975: Marvin Rau, local Permacel representative, stated that tape manufacturers have made substitutions of materials in the past 12 months due to materials shortages. P-223 is now the Permacel designation for 6962 adhesive. Krosche called to state that three 19.5 inch "logs" of P-223 are in stock and can be shipped within two days of purchase order receipt. Krosche stated that no basic change in P-223 chemistry has been made within 12 months. Permacel can manufacture four additional 19.5 inch "logs" by 17 February - 20 February with shipment by 21 February. They will manufacture and ship P-223 with skived TFE release liner at the same time.

20 January 1975: Vought discussed P-223 delivery status with Dave Rosen, NASA/JSC.

21 January 1975: Vought asked Rosen to have the twelve rolls of Ag-Teflon/P-223 delivered to Vought by 10 February 1975. Keith Hudkins, CSD/NASA/JSC, inspected coated heater panels and the as-received GFE Ag-Teflon. Hudkins took sixteen different specimens of defective Ag-Teflon back to NASA.

21 January 1975: Steve Jacobs, SMD/NASA/JSC called for a Ag-Teflon problem status briefing.

23 January 1975: Sheldahl placed P-223 order for 4.5 inch wide material, twelve rolls. Permacel will slit 24 January and ship on 27 January.

31 January 1975: Jerry Maas, Sheldahl shipped 15 rolls of Ag-Teflon by air freight.

4 February 1975: Keith Hudkins, NASA/JSC, wants two inch diameter discs of 0.012 inch 6061 coated with the GFE Ag-Teflon. These are required for an absorptance vs wavelength determination by A. D. Little. Vought must prepare and ship immediately so that A. D. Little can run the absorptance curve before the solar cavity test begins in Chamber B of SESL on 2 March.

13 February 1975: Vought to re-estimate the manhours required to (a) coat the forward and aft orbiter radiators; (b) bond the prime tube heaters to both radiators;

(c) coat the heaters with Ag-Teflon.

14 February 1975: Jerry Maas, Sheldahl, promised shipment of the remaining NASA Ag-Teflon by 28 February 1975.

20 February 1975: Wayne Slemp, NASA/Langley, reported that OSO-H satellite had a solar absorptance of 0.10 just prior to launch, with an absorptance backed-out from thermal data 50 hours after orbit of 0.12. No satellites with Ag-Teflon have been brought back for measurement of absorptance or emittance degradation. After 2.5 years, the absorptance of the Ag-Teflon on OSO-H remained at 0.12 as backed-out from thermal performance. On SAS-B satellite, absorptance was 0.16 initially due to wrinkles and no coverlay protection prior to launch. After 2 years, this property remained at 0.16 as "backed-out". Both OSO-H and SAS-B were near-earth, mostly equatorial orbits, not polar where the degradation problem is projected to be more severe. The only flight experiment within polar, near-earth orbit is OV-10, an Air Force satellite in 1967. No degradation data is available on OV-10. Analysis of IMP-H in a highly eccentric orbit revealed no detectable degradation. Dr. Lehn, WPAFB, has responsibility for flight experiments involving thermal control coatings. NASA/Goddard uses Spraylac to protect Ag-Teflon after installation prior to launch. Methanol/lint-free cotton cloth is used to clean just before launch. A "Kim wipe" saturated with methanol does not seem to scratch the Teflon. If solvent wipe is not used with either Spraylac or the Sheldahl blue Mylar, a darkening of Ag-Teflon is found after 500 e.s.u. of ultraviolet exposure. Jacobs has sent specimens from the RI 60 day radiator design study for UV exposure by Langley. These tests have not been performed. Sheldahl is under purchase order contract with Slemp to prepare 4-5 different adhesives with Ag-Teflon.

NASA/Goddard usually coats satellite details 12 months prior to launch. "Black spots" in the silver start to nucleate into degraded areas on Goddard hardware. These specimens are coated with Spraylac and stored in an open laboratory. They are cleaned prior to flight with an ethanol/cellulose sponge wipe. Vought will prepare and send Slemp

four 1 inch diameter or square Ag-Teflon samples cured on 0.060 inch aluminum. These will be coated with Protex 50 paper. The effect of this protective coverlay paper on degradation of optical properties will be studied. The 4 inch x 12 inch adhesive evaluation samples that Sheldahl has prepared for Slemm have a few "black spots". No coverlay was furnished on these Slemm has never seen "black spots" on Ag-Teflon with a protective coverlay.

Solar absorptance is 0.085 or better at Slemm's laboratory. Langley plans on RFP on "Shuttle Induced Environments on Thermal Control Coatings" in August 1975. Slemm has no hemispherical emittance capability at Langley; Heaney, NASA/Goddard, measures this property. Slemm finds thickness and chemistry very uniform of FEP Teflon, with thickness variations being 0.005  $\pm$  0.0001 inches. A thermal vacuum test of 60 cycles between +250°F and -275°F with a 2.5 hour ramp between the extremes caused solar absorptance of July 1974 Ag-Teflon/585 to change from 0.085 to 0.105. A cure temperature of 250°F for 2 hours gives adequate results for the July 1974 585. The cloth release liner of P-223 leaves a cross-hatched pattern on bonded Ag-Teflon. The P-223 bonds well with a 250°F hot roller. The hot roll process is slow, due to the relatively low thermal mass of the roller, which makes it subject to cooling if large aluminum radiator areas are covered. Slemm thinks hydrocarbon contamination on the Teflon can cause absorptance to become greater than 0.11.

25 February 1975: Harold Howell, Vought, wants eight 2 inch diameter absorptance coupons representing eight different Ag-Teflon batches to be prepared on 0.063 aluminum substrates. These coupons were attached to the out-board edge of the cavity during the chamber B solar exposure test. Optical properties before and after test were determined. The coupons were prepared and installed in the vacuum chamber with the radiator/door/cavity simulator pictured in Figure 8. Figure 10 shows the 2 inch discs on the radiator simulator.

7 March 1975: Howell, Vought, called during the Chamber B test. Bubbles are appearing in certain strips of the Ag-Teflon during hot solar vacuum tests. The bubbles





FIGURE 8. SILVER-TEFLON COATED CARGO BAY DOOR SIMULATOR, LOWER, AND RADIATOR, UPPER, IN CHAMBER B, SESL, NASA/JSC SOLAR TEST. CROSS-HATCH PATTERN IN NEAR PANEL WAS A FIELD-APPLIED BUBBLE RELIEF METHOD.



grow and pulsate as the radiation intensity is increased: the bubbles shrink as the radiation is decreased and the panels cool. Reed, Vought, arrives in Houston to witness test and examine radiators after the chamber is re-pressed. Figures 9 and 10 are views of the radiator/cavity/door test assembly during thermal-vacuum exposure with solar. Notice that no bubbles are apparent on some simulator panels.

8 March 1975: Walt Guy, Branch Chief, CSD, NASA/JSC wants solar absorptance and normal emittance measured in-situ during solar exposure at temperature. No capability exists for this. Numerous bubbles in the silver-Teflon thermal control coating on both radiator and door simulator were observed thru viewing parts in Chamber B. The bubbles expanded as the heat load, both infra red and solar lamp sources, was increased. The load within the cavity exceeded NASA and LTV analytical predictions. Degradation of superinsulation blankets adjacent to the test fixture occurred due to the high heat fluxes, both direct and reflected, near the cavity test article. The thermal degradation of the superinsulation is not usually seen in solar lamp tests of this energy level. The most severe bubbling in the silver Teflon occurred within the cavity some 2 feet outboard of the hinge line. The most probable cause of the bubbling is outgassing of the adhesive on the silver-Teflon in the abnormal thermal conditions in and around the test article. NASA and LTV personnel were anxious to resume testing per schedule at midnight March 10, 1975. NASA requested that the complete area of the thermal control coating be scored or perforated so that the outgassing during solar heating would cause minimum bubbling. Four typical panels were slit on two inch centers in each direction to form a checkerboard pattern. The silver-Teflon on the remaining panels was perforated on 1/2" centers by hand rolling with a spiked rolling tool. Bubbles in the silver-Telfon remaining at ambient pressure were slit and re-pressed to the panel by hand. Approximately 50% of the bubbles had disappeared as the heat load was reduced and pressure in the vacuum chamber was returned to ambient. Certain panels within the cavity showed no bubbling even at the maximum solar heat load. The repairs, scoring, and perforating of the silver-Teflon was completed March 9, 1975.



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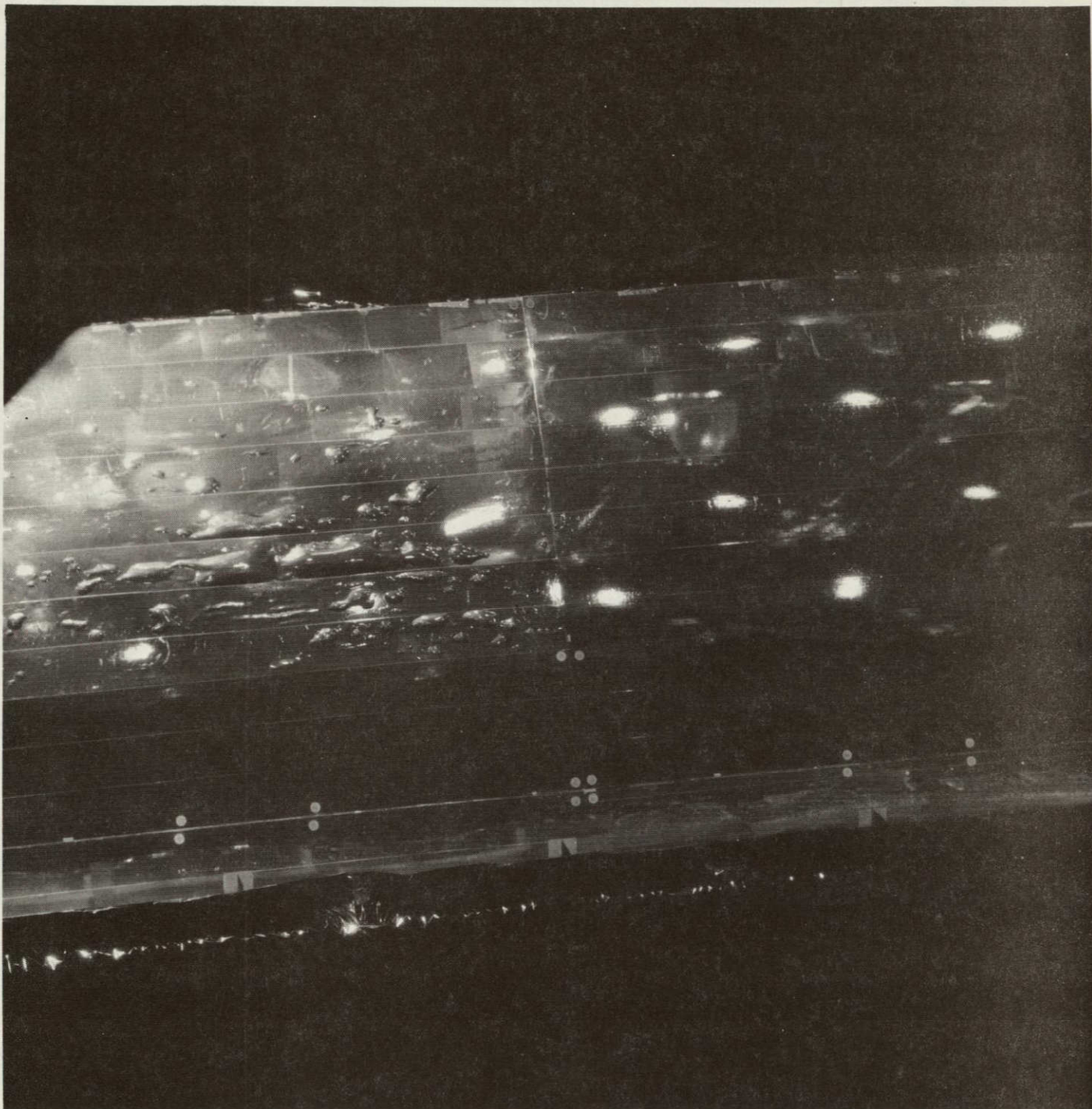


FIGURE 9. FORWARD RADIATOR, CAVITY SIDE, DURING SOLAR EXPOSURE, CHAMBER B, SESL.  
NOTICE ABSENCE OF BLISTERS ON CERTAIN PANELS.





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FIGURE 10. CAVITY BETWEEN FORWARD RADIATOR AND DOOR DURING SOLAR EXPOSURE.  
CHAMBER B. SESL.

Measurements of solar absorptance were made at random over the test panels by NASA and Vought personnel during the repair period with a portable reflectometer. Absorptance values of 0.04 to 0.07 were measured which are normal for Sheldahl production Ag-Teflon. No degradation in this critical optical property was measurable after the solar exposure. The cavity assessment test resumed essentially on schedule the early morning of March 10, 1975.

10 March 1975: NASA/Lewis placed a purchase order for perforated Ag-Teflon with Ag powder added to the 585 adhesive. During cure the Ag loaded 585 tends to fill the perforation holes. The conductive adhesive shorts the Inconel-Ag metal layer to the aluminum radiator structure. The Ag-585 extrudes into the perf holes to touch the Teflon, furnishing a conductive path for any static charge on the Teflon to bleed to ground, i.e., the radiator. Lewis specified a crinoline release liner with TFE on one surface. Some improvement in the surface of the adhesive was seen with this release liner.

11 March 1975: Howell, Vought, calls from Control Console, Chamber B, SESL. The chamber reached the required vacuum level at 0700 10 March 1975 followed by cold wall operation for 12 hours, followed by solar for 14 hours. No bubbles in the Ag-Teflon are evident. Solar energy levels are somewhat reduced but the slitting and perforating have apparently relieved part of the tendency to bubble.

12 March 1975: Howell reports that some bubbles reappeared late in this week's testing in the worst initial areas. Most panels looked good.  $2^{\circ}$  is critical on the angle in the hottest part of the cavity. The last 2 days of the test with variable cavity openings were considered an outstanding technical success.

13 March 1975: Howell telecons that the bubbles were primarily on the radiator simulator. Walt Guy is not satisfied with the bubble relief methods, i.e., slitting and perforating, and wants the hardware refurbished. Reed suggests that vacuum outgassing and perforation be done to the Ag-Teflon prior to installation on the radiators.

14 March 1975: A. D. Little measured hemispherical emittance on Ag-Teflon as 0.78 vs a calculated value of 0.76 from normal emittance.

15 March 1975: Vought recoats two -101 and one -103 panels over weekend, returns them to JSC on 16 March 1975.

17 March 1975: Gil Drab asked that a ROM for recoating the payload bay door simulator with Ag-Teflon be prepared. Drab was not able to determine if the perforations, properly porolations, in the Ag-Teflon on the recoated panels bubbled during test due to cavity orientation:

NOTE: Porolation = punching holes with a spiked wheel or roller.

Perforation = cutting holes and removing the material in the hole with sharpened, hollow tubes on a wheel or roller.

18 March 1975: Gene Hildreth, reported that Sheldahl perforating capability is limited to 2 inch maximum widths with 0.030 inch holes on 1/4 inch centers. Sheldahl perforates the film prior to adhesive application. Hildreth suggested that Perforating Industries, Linden, N. J. has complete perforating facilities.

18 March 1975: Mr. Putnoky, Perforating Industries, furnished the following data:

- (a) 0.045 inch is the smallest practical hole in the Ag-Teflon/P-223 laminate with coverlay.
- (b) 0.051 inch holes, 5 per square inch on approximate 1/2 inch centers results in 1% open area.
- (c) 0.045 inch holes on 13/32 inch centers results in 0.64% open area.
- (d) Putnoky will perforate, re-pack with desiccant, and ship within one week of receipt of the Ag-Teflon.

18 March 1975: Perforated Specialties, N. Y., N. Y. was contacted per Hildreth's suggestion. They request one yard of tape to see if they can perforate.

19 March 1975: Vought discussed the perforating situation with Wil Ellis, CSD/NASA/JSC, and Phil Sheps, Vought/JSC. Sent sample of Ag-Teflon to Perforating Industries by air mail, special delivery.

27 March 1975: Putnoky reported that perforating with the fabric release liner leaves a small burr on the inside of some holes. Aerojet-General has had similar Ag-Teflon perforated successfully.

28 March 1975: Wil Ellis agreed to perforate the remaining 20 rolls of GFE Ag-Teflon with the 0.045 inch x 13/32 inch center pattern like the sample strip. Insured shipment of the GFE Ag-Teflon was made by Air Freight to Perforating Industries.

3 April 1975: Tom Riley, NASA/Lewis, asked for: (a) Ag-Teflon process specification or application technique;

(b) how the adhesive is held off the aluminum until just before bagging;

(Vought advised that it was firmly rubbed on the aluminum);

(c) discussion of the CTS static charging problem.

3 April 1975: Putnoky, Perforating Industries, received the Ag-Teflon tape with perforation scheduled to be complete by April 10.

7 April 1975: Howell advised that heater panel recoating must be complete by 18 April as the test starts in chamber A on 21 April.

8 April 1975: Paul Mock, TRW, reported the coated heat pipe radiator was shipped to Lewis where it has passed thermal-vacuum acceptance testing with infrared, but without solar radiation. It then was subjected to thermal-vacuum test with solar and infrared radiation at NASA/Goddard. CTS launch is scheduled for December 1975 with a probable one-two month slip not associated with the active thermal control system. TRW has given a paper in Europe on the power processor system controlled by heat pipes. TRW suggested that NASA/Lewis call Vought for Ag-Teflon application techniques for coating repair and refurbishment.

9 April 1975: Tom Riley, Spacecraft Technology Division, NASA/Lewis, asked for additional Ag-Teflon bonding process data. He mentioned that Sheldahl was investigating conductive adhesives for STD, and that 585 is the silicone resin adhesive on P-223. The catalyst in P-223 may be different from that suggested by General Electric for 585.

10 April 1975: Perforating Industries shipped the perforated Ag-Teflon back to Vought on schedule by air freight insured.

11 April 1975: Sheldahl reported considerable difficulty in obtaining proper adhesion of Ag to 10 mil Teflon, which is being considered for the Orbiter radiators due to higher emittance. 10 mil Ag-Teflon is produced for Philco-Ford without adhesive. Application of adhesive tends to remove metallized layers from 10 mil Teflon. Au-Teflon is not produced since the gold will not adhere to the Teflon.

Au-Kapton is made as a first surface thermal control coating. The blue Mylar coverlay can be applied to the first surface Au without damage. SiO coated Kapton, Ge coated Mylar, and Ge coated Kapton are also produced to give different emittance ranges.

14 April 1975: Wil Ellis wanted further clarification of the logic for perforating the Ag-Teflon for Walt Guy. R.J. French took various perforated specimens for discussion with Guy.

14 April 1975: Vought refurbished simulator panels with Ag-Teflon.

16 April 1975: Wayne Slemper, NASA/Langley, plans to visit Vought 29-30 April for Ag-Teflon bonding on aft radiator. Slemper suggests a touchup cleaning step just prior to Ag-Teflon layup.

28 April 1975: Vought applied perforated Ag-Teflon to the aft radiator.

1 May 1975: Vought cured Ag-Teflon at 295°F for 2 hours per NASA/JSC instructions. Wil Ellis, NASA/JSC, wanted a 4 hour cure at 295°F per Slemper's request. Vought mentioned the 1/16 inch shrinkage in the TRW panels after a cure of 4 hours at 295°F. Ellis asked Vought to coat four 4-inch x 12-inch coupons for NASA/Langley and A.D. Little absorptance and emittance tests. The cosmetic appearance of the coated radiator was excellent.

6 May 1975: A conference call between Sheldahl (Bill Jacobi and Gary Burdick), NASA/JSC (Dave Rosen and Al Cornelius), and Vought (M.Reed) discussed the defective G.F.E. Ag-Teflon received by Vought early this year.

7 May 1975: Vought prepared memo for Dave Rosen, detailing how defective Ag-Teflon resulted in out of scope work on the modular radiator contract.

7 May 1975: Bill Jacobi, Sheldahl, called to note changes in 467, 585, and P-223 adhesives by the respective manufacturers, 3M, G.E. and Permacel. Jacobi and Maas plan to visit Vought on 21 May.

8 May 1975: Vought prepares a ROM quote on a one half scale forward cavity test article, 15 feet long net. Two each doors and radiators are required, 7.5 feet long each. 96 separate heated zones are required, with 48 zones on each radiator cavity-door assembly. 21 rolls of Ag-Teflon will be required for the program.

9 May 1975: Dave Rosen, NASA/JSC, asked Sheldahl to remanufacture 3 rolls of Ag-Teflon to replace defective material with delivery to occur to Vought by 30 May. Rosen will be out for the next two weeks. Al Behrend, Subsystem Manager, CSD, will handle problems in Rosen's absence. If Vought does not hear from Behrend, the three replacement rolls are ordered. Eleven rolls remain at Vought that have not been accepted or rejected because they have not been inspected.

12 May 1975: Wil Ellis, NASA/JSC, asked for three samples of absorptance specimens, 2 inch aluminum discs coated with Ag-Teflon to be sent in the shipment to JSC on 13 May 1975.

12 May 1975: Ms. Hector, NAVPRO office at Vought Jefferson Street Facility, called to check on the defective GFE Ag-Teflon. Cornelius, NASA/JSC asked Riley, NAVPRO-Vought to look into the defective Ag-Teflon. Ms. Hector requested copies of the receiving records for the GFE Ag-Teflon and the memo to Rosen that listed the defective Ag-Teflon by roll number.

16 May 1975: Ms. Hector requested the Vought stores requisitions showing when the Ag-Teflon was drawn from GFE stores.

16 May 1975: Jerry Maas, Sheldahl, will visit NASA/JSC on 22 May and Vought on 23 May for discussions of current Ag-Teflon problems and anticipated requirements for Shuttle production.

19 May 1975: Ms. Hector asked for additional records, i.e., DD-250 forms for the GFE Ag-Teflon.

20 May 1975: Ms. Hector wanted explanation of the memo to Rosen explaining the defective Ag-Teflon.

23 May 1975: Jerry Maas, Sheldahl, reported that the diffuse Teflon for Slemple/NASA/Langley has cones 0.003" high x 0.015" diameter embossed into one surface of the Teflon. The embossed surface is then metallized. The resulting Ag-Teflon has lower specularities than the conventional material.

4 June 1975: Will advise Rosen that the three replacement rolls have not been received. Vought is assuming that NASA wants the 3 rolls perforated.



5 June 1975: Rosen, NASA/JSC, asked that the three replacement rolls of Ag-Teflon not be perforated when it is received by Vought from Sheldahl.

9 June 1975: NASA/JSC reported the radiator and door simulator were damaged by accidental water flood from the fire control system within Chamber A. Vought cleaned the Ag-Teflon by solvent wipe and assessed damage. The assembly was still usable for thermal-vacuum test. Wil Ellis, NASA/JSC, does not want the last three rolls of replacement Teflon perforated.

9 June 1975: Gene Hildreth, Sheldahl, advised that 5 mil Teflon currently produced by DuPont has many obvious cosmetic defects, such as scratches, fingerprints, and white spots. Hildreth suggests Vought contact DuPont, Circleville, Ohio regarding the Teflon quality.

9 June 1975: Steve Jacobs, NASA/JSC, wants panels 16,17,18,19,26, 27,28, and 29 removed from the radiator simulator for Slemp to recoat with improved Ag-Teflon at NASA/Langley. Vought asked that panels 23 and 24 be substituted for 16 and 17 for ease of removal and re-installation in the test fixture.

16 June 1975: Sheldahl reported shipping three replacement rolls of NASA Ag-Teflon to Vought.

17 June 1975: Shipping dates on the GFE Ag-Teflon were as follows:

<u>Number of Rolls</u>	<u>Date</u>
3	23 December 1974
13	31 December 1974
17	31 January 1975
8	21 February 1975
3 (replacement)	16 June 1975

19 June 1975: Vought applies Ag-Teflon to forward honeycomb radiator.

20 June 1975: Slemp, NASA/JSC was advised that the cavity testing on simulators ends today. Solar absorptance, as backed out from thermal data, appeared lower in these tests than those earlier in the year. With the simulated solar lamps on, lower temperatures were measured. The television camera in the early tests may have added infrared radiation in the early tests.

24 June 1975: Vought began application of Ag-Teflon to the aft honeycomb radiator. Both perforated and non-perforated Ag-Teflon was used.

24 June 1975: A telecon with Ellis, Hudkins, (NASA/JSC), Sheps, French, Drab, Howell, Reed (Vought) reported that the cavity test was still in progress with 1.1 equivalent sun units (e.s.u). The cavity is averaging about 61°F cooler overall in the tests this past week than in the earlier work. Peel tests can be run on the Ag-Teflon, if it is suspected the adhesive has delaminated; refurbishment at Vought would be required.

24 June 1975: E.L. Mulcahy, Supervisor, SES Laboratory, Vought, stated that a  $\pm$  15% variation is possible in the solar radiation output of the lamps in Chamber B even with careful monitoring. This is the first large scale test of the Chamber B lamps. Mulcahy worked on design of the Chamber B solar lamp system.

27 June 1975: Vought cures Ag-Teflon on the forward honeycomb radiator panel.

30 June 1975: NASA asked for spares list of coated panels for the simulated radiator-door test article.

2 July 1975: Hudkins, NASA/JSC, wants a panel removed, adjacent to one of the Langley coated panels, and coated with current production perforated Ag-Teflon. Panel 27 will be removed and returned to Vought for recoating.

2 July 1975: Vought sends 60 feet of roll 1921 NASA/JSC Ag-Teflon to Slomp for coating simulator panels.

3 July 1975: Vought repairs simulated Ag-Teflon edge delaminations with these combinations of adhesive/catalyst:

- Eastman 910/no catalyst
- Eastman 910/catalyst #200
- Loctite 04E/no catalyst
- Loctite 04E/catalyst #200
- Loctite 312/no primer
- Loctite 312/primer NF

10 July 1975: Emerson Horning, General Electric, Watertown, N.Y., stated that the SRC-18 catalyst for 585 is an amino-silane. Benzoyl peroxide should be used as a catalyst on 585 systems which are laminated after cure since benzoic acid is evolved during cure with 585. This can cause bubbles and is a possible explanation of the bubble problem in early 1975 if Sheldahl catalyzed with benzoyl peroxide.

18 July 1975: NASA requested a ROM quote on recoating the forward radiator panel due to edge delaminations.

22 July 1975: Chuck Statham, RI/JSC, was advised that we were preparing Ag-Teflon specimens of rolls 1915 and 1918 on curved panels for peel tests.

23 July 1975: Slemp, NASA/Langley, reported edge peel after 4-5 days after vacuum outgassing the Ag-Teflon at 140°F. Slemp received the simulator radiator panels for coating on 17 July. They were in JSC Shipping Depts. on 1 July, left Houston by Roadway Express on 7 July and arrived at Langley on 15 July.

23 July 1975: Wil Ellis, NASA/JSC, asked that Vought measure peel strength of the Ag-Teflon installed in Chamber A per Walt Guy's request. The forward radiator simulator on the cavity angle gimbal fixture, the aft "L"-tube radiator, and the forward, "L"-tube radiator with door simulator are pictured in Figure 11 after installation in Chamber A/SESL/NASA/JSC for thermal vacuum tests with active Refrigerant 21 fluid loops.

24 July 1975: Vought measures peel strength of Ag-Teflon on radiators/edge peel, the RI life cycle panel, and control panels using calibrated push-pull spring scales, from the Vought Tool Grib. Rate of pull was 2-3 inch/10 seconds.

The results are given in Table 2 as follows:

TABLE 2      Ag-TEFLON PEEL STRENGTH

<u>Specimen Identification</u>	<u>Cure Date</u>	<u>Peel Strength</u> <u>lb./inch width</u>
RI Life Cycle	June 1974	2.1 lb/in 2.2 lb/in.
NASA Ag-Teflon Control	June 1975	9.6 lb/3.75 inch 9.8 lb/3.8 inch
NASA Ag-Teflon Control	23 July 1975	2.6 lb/0.9 inch 3.25 lb/0.94 inch 3.4 lb/0.94 inch 3.2 lb/0.94 inch (in perms)
Aft Radiator Control	March 1975	14 lb/3- 13 lb/3-13/16 inch 16 lb/3-13/16 inch (Wil Ellis retains specimen)
Roll 1918 Control	23 July 1975	2.75 lb/15/16 inch 3.00 lb/15/16 inch
Roll 1918 on Aft Radiator (Curved Surfaces)	June 1975	10 lb/4 inch 11 lb/4 inch 9 lb/4 inch 10 lb/4 inch
Aft Panel, Strip 12 from outer edge	June 1975	5.5 lb/4 inch
Aft Panel, outer edge strip	June 1975	9 lb/4 inch

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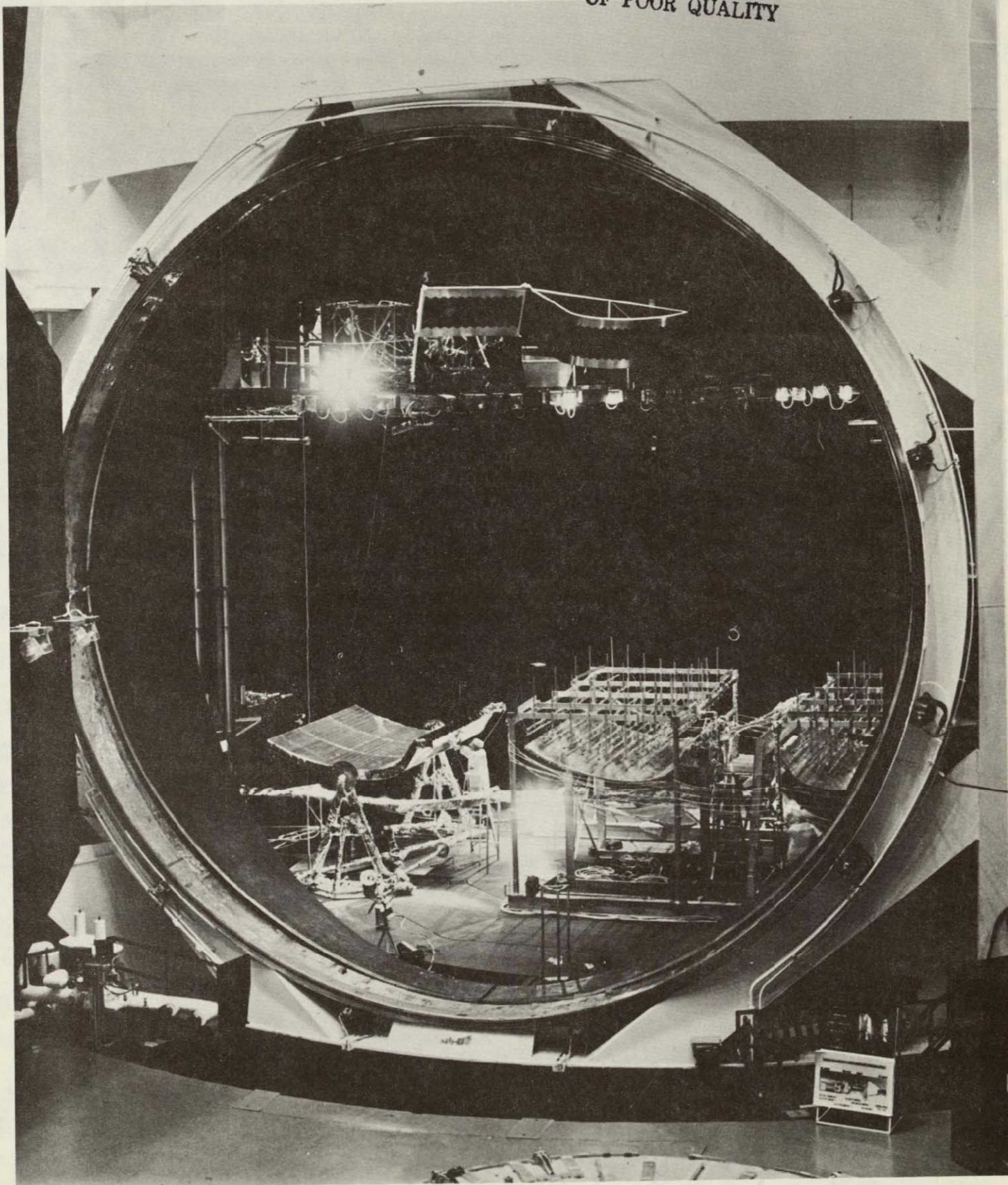


FIGURE 11. AFT AND FORWARD RADIATOR AND RADIATOR SIMULATOR IN CHAMBER A, SESL, NASA/JSC THERMAL-VACUUM TEST.

The coating had released at edges 1/4" to 1/2" from the edge in lengths of 2" to 12". The affected area was roughly 2% of the radiator surface. The damaged areas were repaired with Loctite 04E/12 cyanoacrylate adhesive. This is a competitive version of Eastman 910. This fix was recommended based on test panels peeled and repaired at Vought in early July.

A portable peel test rig was devised for measuring the peel strength of the coating on the radiator mounted in Chamber A of SESL at JSC. Peel strengths of 1.4 - 2.2 lb/in were measured on the coating with defective edges. Vought recommended that the thermal-vacuum test proceed with the repaired Ag-Teflon.

11 August 1975: Vought received Orbiter Radiator Production Contract from Rockwell International.

14 August 1975: Wil Ellis, questioned the origin of the texture on the cured Ag-Teflon on the radiators. Vought stated it was normal pattern from the P-223 adhesive cloth liner. B. French, CSD/NASA/JSC, reported that Slemple will visit JSC 20-22 August to witness the conclusion of the combined radiator-door testing in Chamber A.

15 August 1975: Jacobs, NAS/JSC, advised that Slemple will delay visiting JSC until 27-29 August due to rescheduled test time line. Jacobs asked that Vought give a presentation at JSC at the same time on current Ag-Teflon problems and processes. Jacobs and other SMD Materials personnel plan to visit Vought in the Fall of 1975 for further discussions.

18 August 1975: Dr. H.I. McHenry, National Bureau of Standards, Boulder, Colorado has no specific cryogenic properties data on cyanoacrylates. NBS has used Eastman 910 for 10 years to bond strain gages for cryogenic test work. NBS has recently changed to McMillian strain gage adhesive which is repackaged 910.

21 August 1975: Jacobs, NASA/JSC, asked that Vought give the current Ag-Teflon application procedure when we visit on 29 August.

22 August 1975: Wil Ellis, NASA/JSC, reported that 2 of 8 panels, that Slemple coated, bubbled during the current testing. The forward and aft radiators have 5-6 bubbles between them, silver dollar size.



27 August 1975: Jacobs, NASA/JSC, reported that panels 18 and 24 which were coated by Langley bubbled in the +100°F excursions in Chamber A testing. Drab, Vought, said that two of the Langley panels bubbled but all the bubbles disappeared when the heat source is removed. Hudkins, NASA/JSC, reported that Gordon Chandler, RI/Downey, was leaving prior to completion of the test on 28 August. Wil Ellis advised that Chandler will remain through completion of the testing.

29 August 1975: Coating Improvement Meeting (informal) with Dr. Lubert Leger, Steve Jacobs, Ike Spiker (SMD/NASA/JSC), Joe Conti (McDonnell-Douglas/JSC), Wil Ellis (CSD/NASA/JSC), Blu Welch, Gordon Chandler (RI), Dr. Roy Cox, M. W. Reed (Vought), and Wayne Slemm (NASA/Langley) attending was held. Slemm reported that S-13 G-L0 paint was currently priced at \$200/pint when buying in quantity. 100 square feet can be covered with S-13 G-L0 for \$500 material cost vs \$600 for Ag-Teflon. The new pigment from IITRI costs \$700/pint when made into paint. Solar absorptance of Ag-Teflon is 0.085 typ vs 0.21 - 0.24 for S-13 G-L0 with a 5 - 7 mil thickness. Vought reported that Ag-Teflon was applied by the following process:

I. Pre-Condition: Vacuum Oven Outgas Ag-Teflon on Roll

14 Days, 150°F

II. Surface Preparation:

(a) Per CVA 8-51, Aluminum Cleaning and Etching for Bonding.

(b) Alternate Method for Complex Assemblies

- 1) Hand Sand/120 Grit  $Al_2O_3$  Abrasive Cloth
- 2) MEK Wipe
- 3) Abrasive Pad/MEK Rub
- 4) MEK Wipe
- 5) Wipe Dry/Cheesecloth

III. Ag-Teflon Application:

- (1) Remove cloth release liner

- (2) Apply Ag-Teflon laminate to cleaned aluminum, taking care not to entrap air to form bubbles.
- (3) Hard rub the Ag-Teflon with cloth pad.
- (4) Vacuum bag the coated assembly.

#### IV. Cure:

- (1) Place bagged assembly in circulating air oven
- (2) Heat per the following schedule:
 

2 hours	145°F
1/2 hour	195°F
1/2 hour	245°F
1 hour	295°F
- (3) Cool under vacuum to ambient temperature.

Vought proposed these Ag-Teflon problem areas as needing attention:

- (a) Adhesive life, aging, storage conditions.
- (b) Adhesive pre-conditioning.
- (c) Bleeder cloth over Ag-Teflon during cure, effects on absorptance and emittance.
- (d) 10 mil Teflon for improved emittance.
- (e) Refurbishment.
- (f) Cleaning contamination from Teflon due to ground handling.
- (g) Thruster contamination.
- (h) Static charge relief.

Vought suggested that technical areas such as these are addressed in Ag-Teflon research and development work sponsored by NASA:

- (a) Establish verification method for optical/mechanical properties of Ag-Teflon coating between flights.

- (b) Investigate methods for relief of static charge buildup on Ag-Teflon.
- (c) Ag-Teflon material spec.
- (d) Ag-Teflon process spec.
- (e) Evaluate effect of solar radiation TBD and high energy particles TBD on Ag-Teflon coating applied to radiator panel.
- (f) Outgassing of Ag-Teflon adhesive.
- (g) Evaluate effect of perforations and static charge relief method.
- (h) Demonstrate techniques for coating refurbishment on full panels and local areas. Verify that Ag-Teflon peel in refurbished areas is the same.
- (i) Evaluate effects of sand and dust on coated radiator panel.  
Measure absorptance and emittance before and after test with portable instrumentation.
- (j) Measure surface properties of one ship set of coated radiators with portable instruments.
- (k) Evaluate protective overlays and/or coatings for Ag-Teflon.

Ike Spiker, SMD/NASA/JSC suggested a tightly woven Beta glass cloth as a bleeder during Ag-Teflon cure: Spiker furnished sample to Vought for evaluation. 1 October is tentative meeting date with SMD/NASA/JSC and NASA/Langley at Vought.

3 September 1975: Berl French, NASA/JSC, reports these solar absorptance measurements made at Langley and A. D. Little:

	Roll 1887-3	Roll 1895-3
Absorptance - ADL	0.067	0.069
Absorptance - Langley	0.082	0.080
	0.081	0.082

B. French will forward the name of the designer of the MS251 portable solar reflectometer made by Gier-Dunkle. The designer may suggest circuit modifications to give more stable operation.

4 September 1975: Slemp, NASA/LaRC, provided the information given in Table 3 on the simulator panels coated at Langley for the combined radiator cavity for the combined radiator cavity-door test just completed in Chamber A/SESL. The test assembly is diagrammed in Figure 12, showing panel locations by number. The Ag Teflon used in these studies is shown schematically in Figure 13. Application notes and problems that occurred during processing at LaRC are discussed by simulator panel number.

Panel 16 was laid up using SR585 of pre-1975 manufacture with a 0.004 in. adhesive thickness. The 585 of current manufacture has a thickness of 0.002 - 0.003 in. To achieve proper lay-up of the 585/Ag-Teflon, removal of the protective coverlay was necessary. Scratches during lay-up and handling were thus introduced into this coating. The edges of the tape were without adhesive for 1/4 in. at each edge, necessitating that each strip be overlapped and trimmed. The 585 allowed the Ag-Teflon to shift during the cure cycle. It had pulled slightly from the edges; at 275°F the tape had expanded until each strip was touching. When cooled, the gap was again about 1/16 in. The chemistry of 585, and subsequent P-223, was rumored to have changed in mid-1974 due to shortages in the chemical process industry. Similar shortages affected the quality of the FEP Teflon film in the 42 roll order of Ag-Teflon used in the Chamber B and Chamber A radiator cavity tests.

Panel 17 was coated with Ag-Teflon having an elemental nickel layer substituted for the Inconel nickel-chromium alloy protective layer. The nickel was chosen due to low solubility in the silver. The lack of solid solubility would inhibit diffusion into the silver while furnishing mechanical protection. Diffusing a second element into silver increases the solar absorptance, causing an unfavorable change in the optical properties of the coating. Defects in the tape included (a) some spots that were totally void in the metallized layer, and (b) no adhesive in the P-223 intermittantly along the edges; panel was overlapped and trimmed during lay-up due to edge defects. The cosmetic appearance of panel 17 was excellent.

TABLE 3  
NASA/LaRC COATED RADIATOR PANELS

<u>PANEL NO.</u>	<u>ADHESIVE</u>	<u>CURE CYCLE</u>
16	SR 585/Old Manufacture	150°F - 1 hr., 250°F - 1 hr., 275°F - 3 hr.
17	P223/Nickel Sub- stituted for Inconel	150°F - 1 hr., 200°F - 30 min. 250°F - 30 min., 295°F - 1 hr.
18	6962/Teflon Release Liner	150°F - 1 hr., 200°F - 30 min., 250°F - 30 min., 295°F - 1 hr.
19	P-223	150°F - 1 hr., 200°F - 30 min., 250°F - 2 hr., 275°F - 1 hr.
23	P-223	150°F - 1 hr., 200°F - 30 min., 250°F - 30 min., 295°F - 2 hr.
24	P-223/Perforated/ Vought Supplied	150°F - 1 hr., 200°F - 30 min., 250°F - 1 hr., 275°F - 3 hr.
27	P-223	150°F - 1 hr., 200°F - 30 min., 250°F - 30 min., 310°F - 2 hr.
28	P-223	150°F - 1 hr., 200°F - 30 min., 250°F - 2 hr., 295°F - 1 hr.
29	P-223	Vacuum bag only (no thermal cycle)

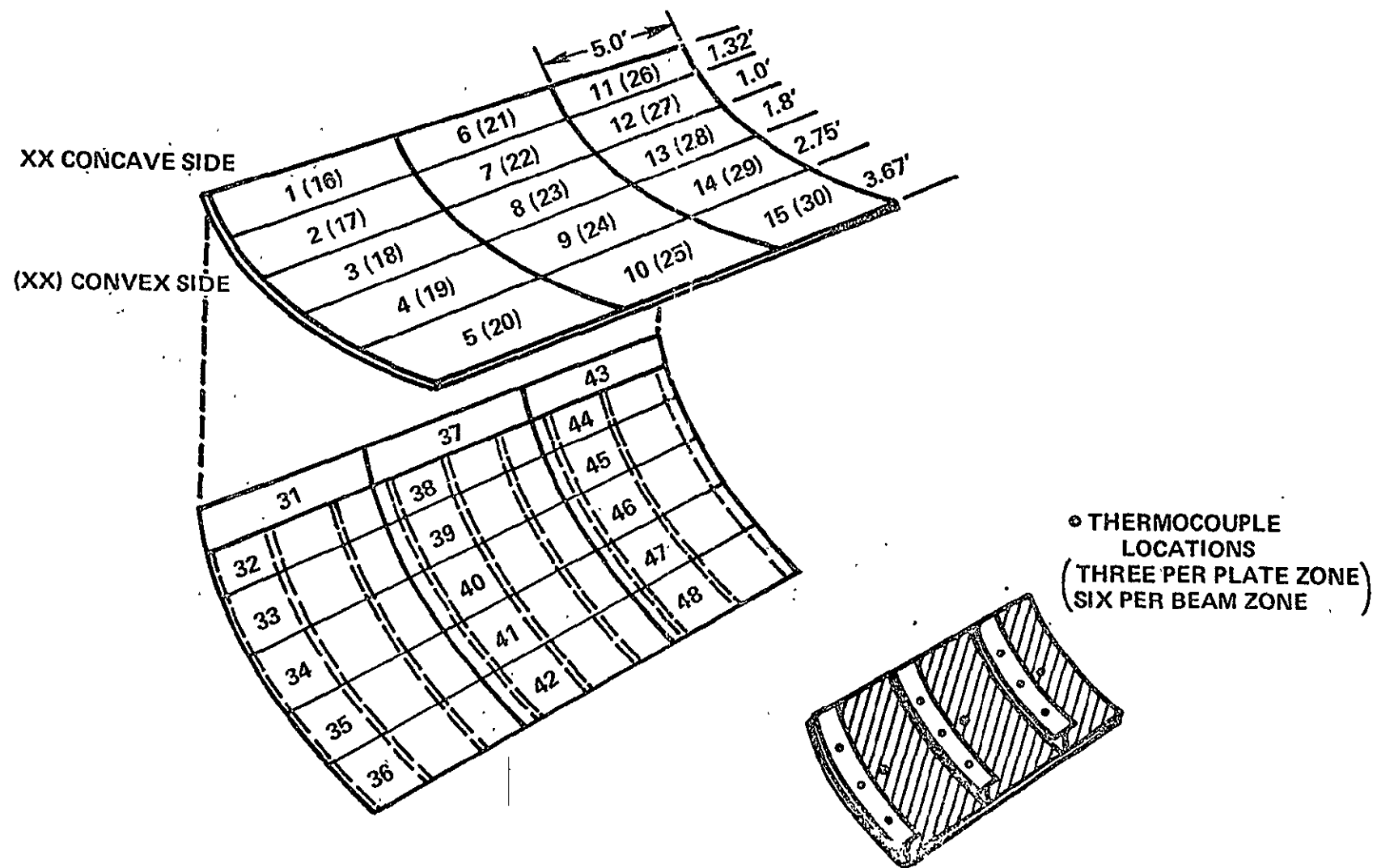


FIGURE 12 CAVITY ASSESSMENT TEST ARTICLE WITH DETAILED PANEL OR ZONE NUMBERS



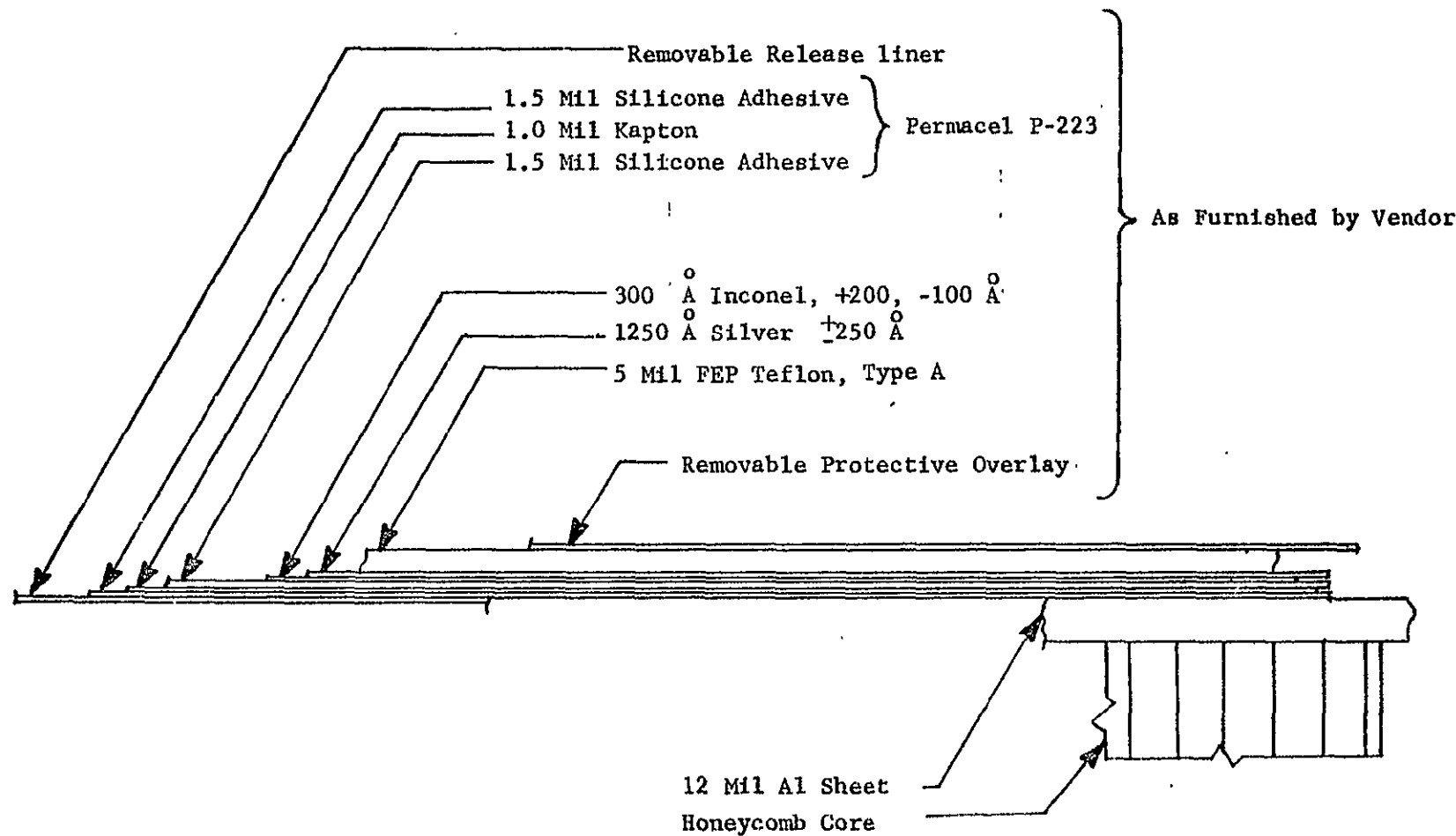


FIGURE 13 SILVER-TEFLON THERMAL CONTROL COATING SCHEMATIC DIAGRAM

Panel 18 had small bubbles after cure. The 6962 (designated currently as P-223) had a 0.002 in. TFE release liner which appeared to prevent proper degassing of the solvent during the vacuum outgassing cycle prior to lay-up.

Panel 19 had bubbles visible through the vacuum bag at the 275°F cure temperature; after cooling to ambient temperature and pressure the bubbles were not present.

Panel 23 had an excellent finished appearance.

Panel 24 was coated with perforated P-223 tape similar to both the forward and aft radiators in the Chamber A tests. Some bubbles were noted during cure through the vacuum bag at temperature; these were not present at ambient pressure and temperature. The perforated P-223 Ag-Teflon was the easiest to apply of the coatings evaluated.

Panel 27 had an excellent cosmetic finish.

Panel 28 had an excellent appearance after cure.

Panel 29 was coated with P-223 with vacuum bag only as cure (no thermal cycle). It had the poorest quality of all panels, leaving many small bubbles in the Ag-Teflon.

All panels except 16 and 24 bubbled during the thermal-vacuum test in Chamber A/SESL.

5 September 1975: R. L. Cox, Vought, requested after 5 P.M. that M. W. Reed visit NASA/JSC 8 September 1975 to inspect delaminated Ag-Teflon.

8 September 1975: Reed, Vought, met with Walt Guy, Noel Willis, Wil Ellis, Keith Hudkins, and Al Behrend at Chamber A. Guy wanted procedure that will avoid most Ag-Teflon adhesive problems. Vought suggested: (a) test panels from each roll to check for peel, bubbling tendency during cure, edge delaminations after cure, and delaminations during and after thermal-vacuum test; (b) better vendor quality control on the adhesive; (c) micro-balance weight loss as a quality control test for acceptance of each roll; (d) moisture in the release liner could contribute to the bubbling or delamination problem. Tap testing by Reed, Vought, and Spiker, SMD, was performed to verify the honeycomb bond. No voids were detected. Overall performance of the bonded, Ag-Teflon coated radiators was considered excellent by consensus opinion of NASA, RI, and Vought engineers in the Chamber A test program.

9 September 1975: Jacobs, NASA/JSC, plans to visit Vought on 9 - 10 October for detailed planning of future Ag-Teflon work. Rockwell International and NASA/Langley have been invited to attend.

10 September 1975: Vought sent 7 inch lengths from Ag-Teflon roll numbers 2551 and 2552 for outgassing studies by SMD/NASA/JSC, attention: Steve Jacobs.

16 September 1975: Howell, Vought asked for ROM quote on Ag-Teflon for coating one surface of an 11 foot x 15 foot Orbiter radiator. 6.5 rolls are required with 1 roll extra as contingency.

23 September 1975: Howell requested further refinement of the estimate to coat a forward radiator panel with Ag-Teflon.

30 September 1975: Vought sent the following supplies to Drab at JSC for repair of Ag-Teflon on the forward radiator and payload bay door: 6 syringes, 12 needles, 3 1-oz. bottles Eastman 910.

1 October 1975: Jacobs, NASA/JSC reported the outgassing weight loss data plotted in Figure 14.

9-10 October 1975: A meeting at Vought Corporation, Marshall Street Facility, was convened to discuss Ag-Teflon problem areas. Attendees were Dr. Lubert Leger and Steve Jacobs NASA/JSC/SMD, Wayne Slemp, NASA/LARC, Mal Clancy, Rockwell International, and Dr. R. L. Cox and M. W. Reed, Vought. A key purpose of the meeting was to minimize duplication of testing and development efforts relating to Ag-Teflon. Each organization presented outlines for current and planned investigations of Ag-Teflon problem areas. Informal discussions resulted in reassignment of some tasks between NASA, RI, and Vought. The principal new technical effort recognized at the meeting was the need for an autoclave cure process for the Ag-Teflon applied to Orbiter Radiators. Vought will have responsibility for development of the autoclave cure process on modification to the existing Modular Radiator Contract with NASA/JSC/CSD. NASA/JSC/SMD personnel will monitor this development effort for CSD.

11 October 1977: A sketch of Communications Technology Satellite is shown in Figure 15; launch was successful in January 1976.

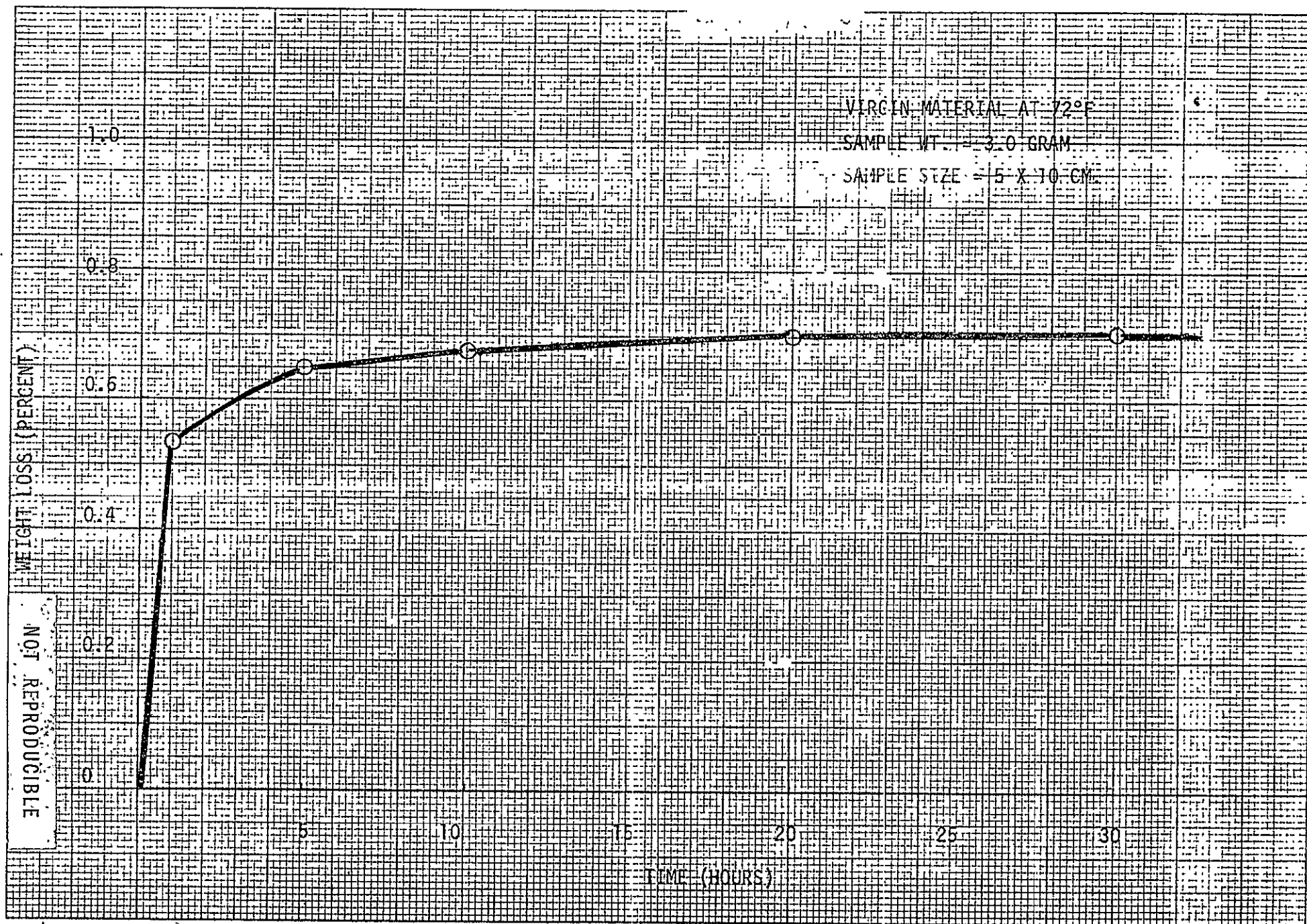


FIGURE 14 WEIGHT LOSS VS. TIME FOR SILVER-TEFLON/P-223 ADHESIVE

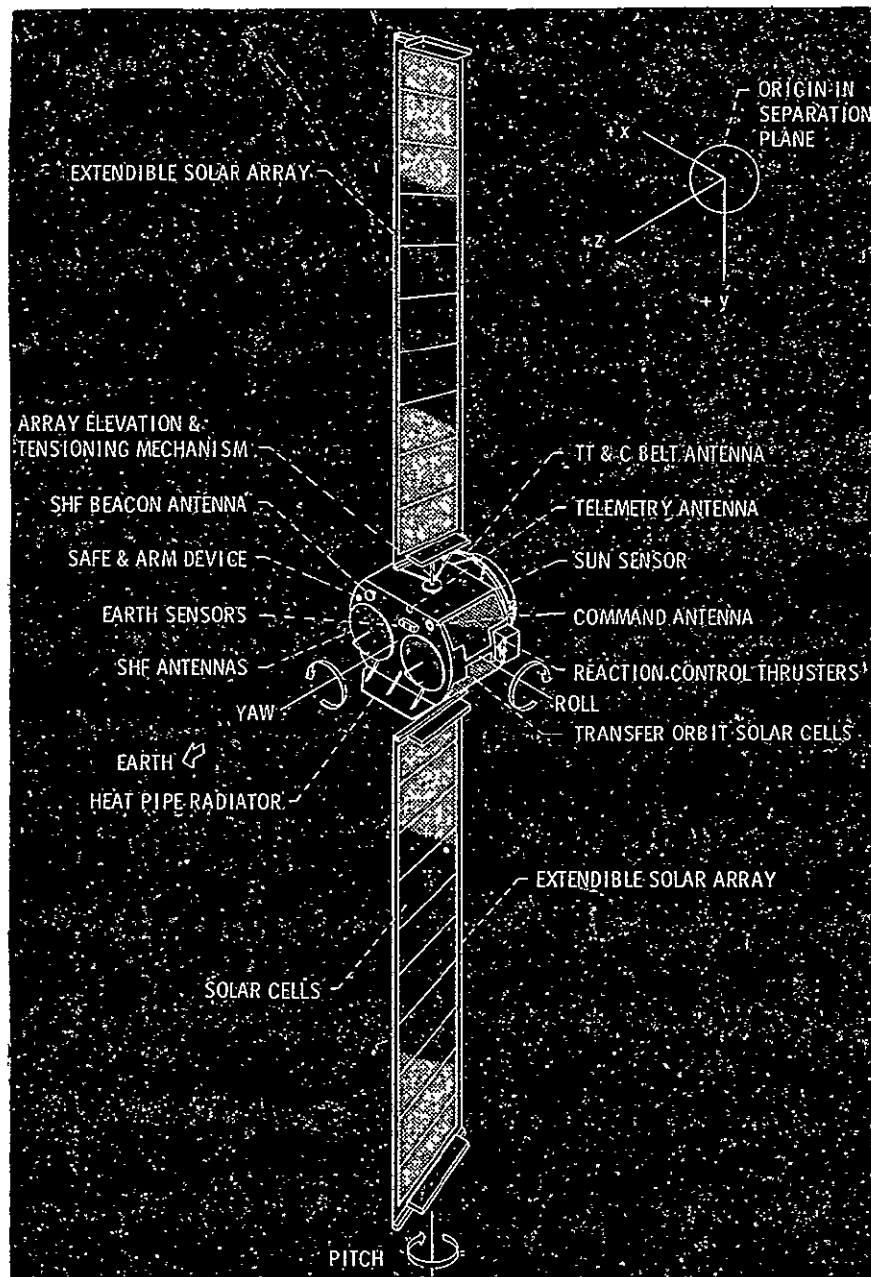


FIGURE 115: COMMUNICATIONS TECHNOLOGY SATELLITE: WEIGHT WAS 1485 LB WITH A SPAN OF 52 FT., 9 IN.



#### 4.0 CONCLUSIONS

The technology for application and use of silver-Teflon laminate type coatings was advanced from laboratory scale production to reproducible manufacture in quantities to coat Space Shuttle sub-systems. Real time solutions to problems such as perforation, porolation, vacuum outgassing, field repairs, and refurbishment were evaluated and demonstrated successfully. The testing and environments, such as solar, thermal-vacuum, and water flood, imposed on the various silver-Teflon coated hardware resulted in cosmetic changes, but did not affect thermal performance or mechanical properties.



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Vought Corporation • Post Office Box 5907 • Dallas, Texas 75222